NOMINATION REPORT

for the

PEATS FERRY BRIDGE

HAWKESBURY RIVER, NSW

as an

Historic Engineering Marker

The welded steel trusses of the 1945 bridge

Plaquing Ceremony
in conjunction with the
Roads and Traffic Authority and
60th Anniversary of the National Trust
during
National Trust Heritage Festival 2005
Sunday 17 April

Prepared by Don Fraser
for the
Engineering Heritage Committee
Engineers Australia, Sydney
October 2004

CONTENTS

Plaque Nomination Form

The Administrator
Engineering Heritage Australia
Engineers Australia
Engineering House
11 National Circuit
BARTON ACT 2600

Name of Work: **Peats Ferry Bridge**

The above-mentioned work is nominated to be awarded a

Historic Engineering Marker

Location, including address and map reference:

Pacific Highway, Hawkesbury River, NSW

Owner (name and address):

Roads and Traffic Authority, NSW

The owner has been advised of this nomination, and agreement identified:

Letter attached

Access to site:

Public bridge

Nominating Body:

Engineering Heritage Committee, Sydney.

Chairman *Glenn Rigden*

Engineering Heritage Committee, Sydney

Date: *October 2004*

98M2034
P B Manamperi
Phone 9218 6710

RTA

-1 NOV 2004

Mr Don Fraser
Plaquing Coordinator
Engineering Heritage Committee Sydney
Engineers Australia, Sydney
PO Box 2044
Rose Bay North NSW 2030.

Dear Mr Fraser,

PLAQUING PEATS FERRY BRIDGE, HAWKESBURY RIVER

Reference is made to your letter dated 3 September 2004 addressed to the General Manager, Infrastructure Maintenance regarding the proposal for placing a recognition plaque on the Peats Ferry Bridge over the Hawkesbury River at the 2005 National Trust Heritage Festival.

I agree in principle to the Engineers Australia proposal for the Historic Engineering Marker plaquing of the Peats Ferry Bridge as part of the 2005 Heritage Festival.

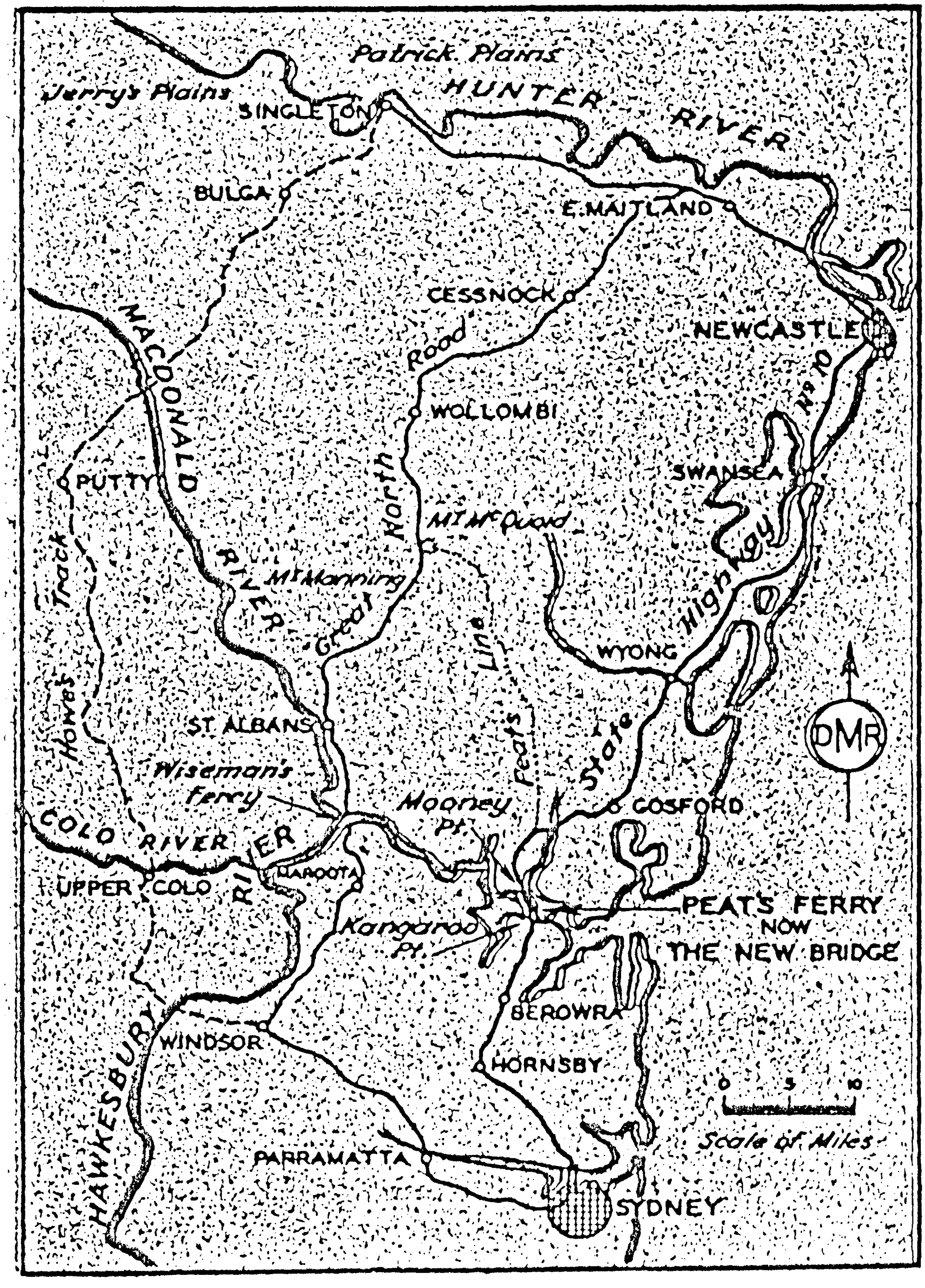
Mr Neil Forrest, Asset Manager, Sydney Region is nominated as the contact officer for this project. He will advise on a suitable location and will arrange for installation of the plaque. Further he will be the contact regarding the timing and any arrangements regarding the unveiling ceremony for the plaque.

Mr Forrest's contact details are given below:

Address:	83 Flushcombe Rd.
	Blacktown NSW 2148
Telephone:	(02) 8814 2933
Facsimile:	(02) 8814 2111

Yours sincerely

Paul Forward
Chief Executive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Jerry's Plains
SINGLETON
BULGA
E. MAITLAND
CESSNOCK
NEWCASTLE
MACDONALD RIVER
Great North Road
WOLLOMBI
PUTTY
SWANSEA
Nº 10
Mt McQuoid
Howes Track
Mt Manning
State Highway
Peats Line
WYONG
ST. ALBANS
DMR
Wiseman's Ferry
Mooney Pt.
GOSFORD
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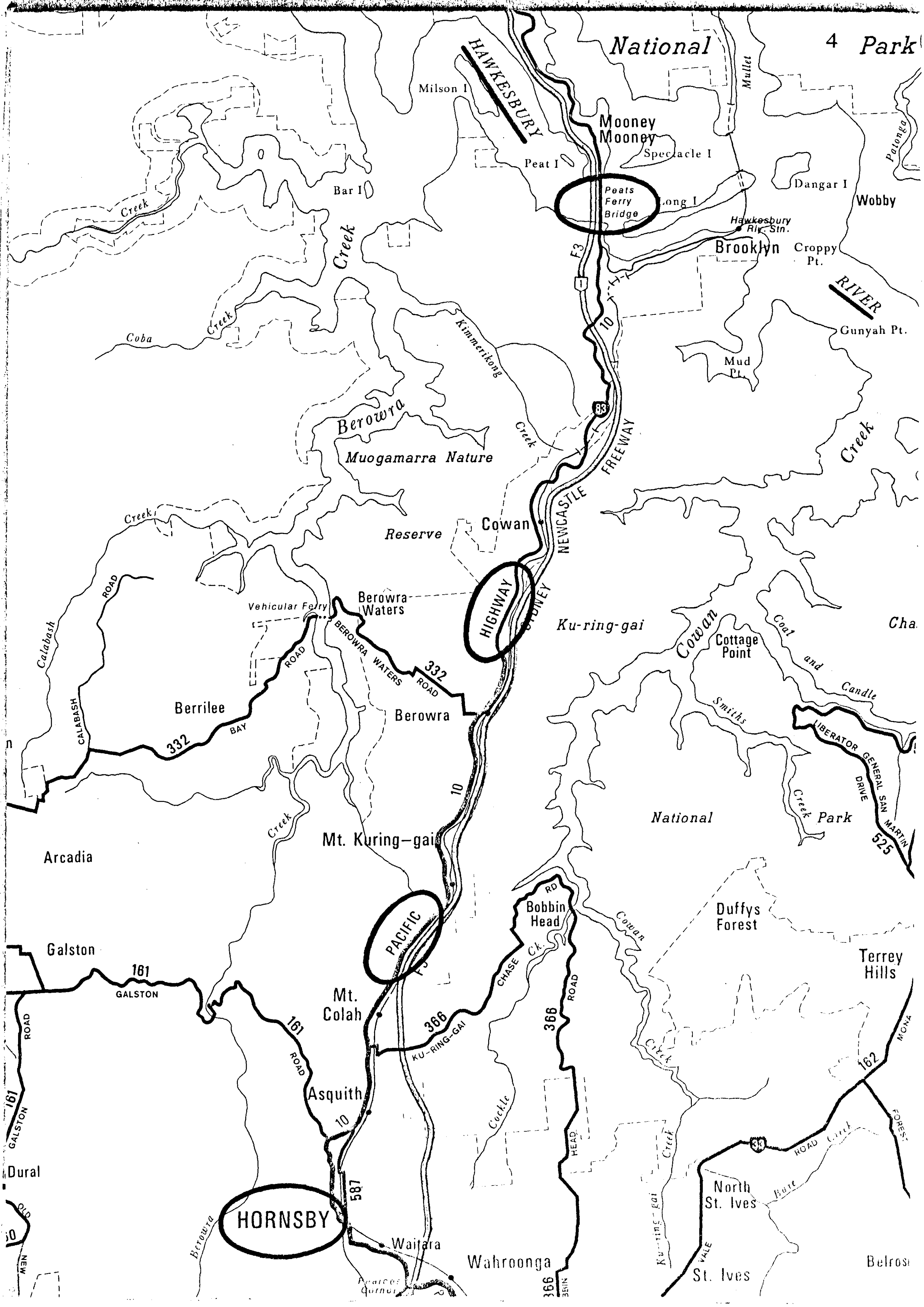

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Peat I
Peats
Ferry
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Long I
Dangar I
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Kimmerikong
Mud
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Patonga
Berowra
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Muogamarra Nature
Reserve
FREEWAY
NEWCASTLE
Creek
Cowan
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SYDNEY
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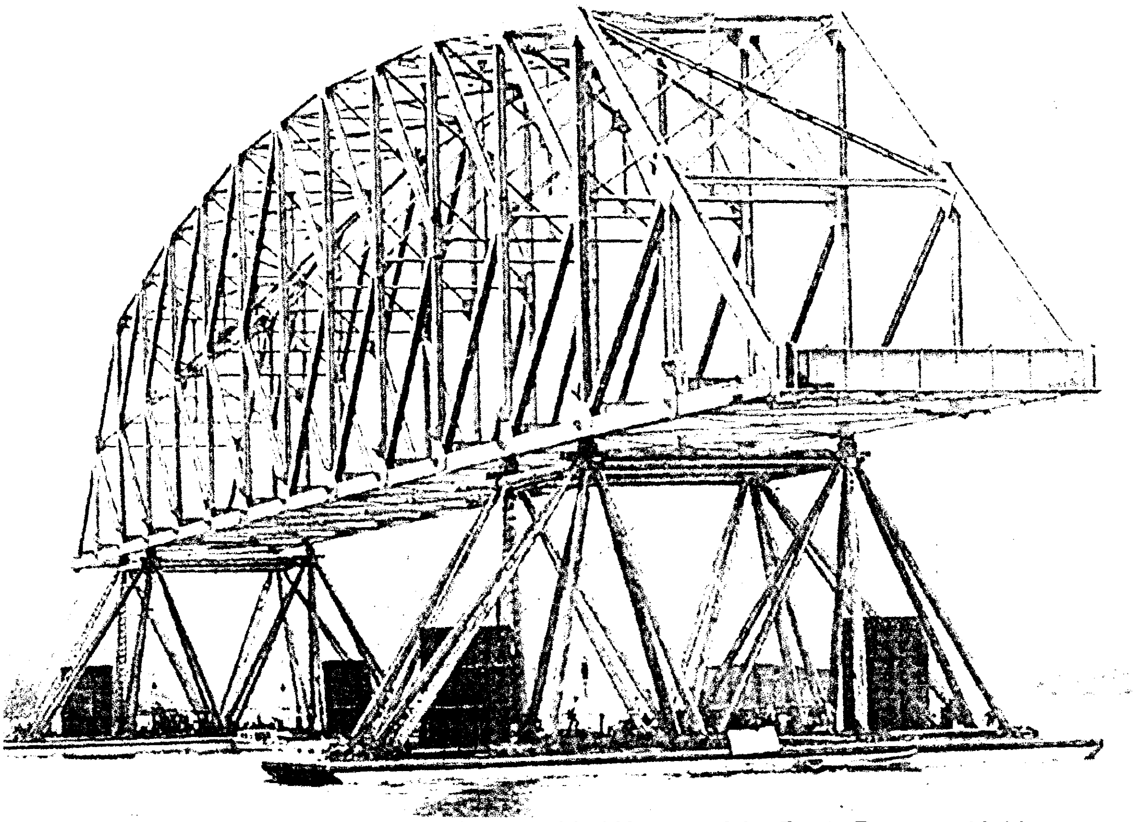
Introduction



Typical floating out in 1944 of a large welded K-truss of the Peats Ferry road bridge

Any bridge across the drowned river valley of the Lower Hawkesbury River has had to be a major engineering work. So it has been for the 1889 railway bridge and its replacement in 1946, and the 1945 bridge for the Pacific Highway. The railway bridges through the association with the Father of Federation, Sir Henry Parkes, were plaqued as National Engineering Landmarks during the Centenary of Federation 2001.

The Peats Ferry Bridge, built during the demands of World War II set world bridging records and had technical innovations that rank it as a work of significant engineering heritage. Planning began in 1926 to replace the under-capacity ferry service for the increasingly busy and important Pacific Highway and was carried through to completion by the Department of Main Roads using its own engineering staff and local industries, particularly the historically significant Clyde Engineering (formerly Hudson Brothers), a truly Australian achievement.

The principal aspects of engineering significance are,

(1) the single caisson-pier at the junction of the two steel trusses was founded 241ft (73.5m) below low water level, the second deepest in the world.

(2) the extensive use of welding to fabricate the large structural members for the trusses.

(3) the K-trusses at 438ft (133.5m) span were the largest steel trusses for road bridgework in Australia.

The bridge has good aesthetic lines within the surroundings of the river valley.

It has provided enormous social benefits for the east coast of Australia, particularly to communication north of Sydney and to the Central Coast of NSW.

Plaquing Nomination Assessment Form

1. BASIC DATA

Item name: Peats Ferry Bridge

Other/Former Names:

Location: Hawkesbury River, NSW

Address: Kangaroo Point, NSW

Suburb/Nearest Town: Brooklyn, NSW

State: New South Wales

Local Government Area: Hornsby Shire

Owner: Roads and Traffic Authority, NSW

Current Use: Road bridge

Former Use:

Designer: Engineering staff, Department of Main Roads

Maker/Builder: Clyde Engineering Co. Ltd.
Balgue Constructions Pty. Ltd.

Year Started: 1939 **Year Completed:** 1945

Physical Description: The bridge consists of three parts,

(1) at the Sydney (southern) end there are two large, welded steel, K-trusses each 440ft 10in ft (134.35m) supported on a concrete shore pier, a deep caisson pier and a concrete pier on deep piles, a combined truss length of 881.67ft (268.9m),

(2) a viaduct of 8 x 90ft (27.4m) welded steel plate web girders on pile-supported concrete piers, length 723.67ft (220.7m),

(3) a viaduct of 8 x 40ft (12.2m) rolled steel beams supported pile-supported concrete piers, length 320.67ft (97.8m).

Total length of bridging is 2005.6ft (611.7m)
There is a reinforced concrete deck throughout.

Physical Condition: Good, is well maintained

Modifications and Dates: No major structural changes – some minor works to accommodate service ducts and piping.

Historical Notes: *Based on material in the commemorative booklet produced by the Department of main Roads, see Appendices.*

The deep drowned river valley of the Lower Hawkesbury River (see location map) has always been a major barrier for land transport to regions north of Sydney. Consequently, shipping along the river and along the coast dominated passenger and cargo services for most of the colonial era of NSW.

The first manageable road links to the Hunter River were some 50km west, from Windsor to Singleton c1820, and from Wiseman's Ferry to Wollombi and Newcastle, 1830 (see location map). Although they are still in use they represent long, tortuous deviations from a more direct Sydney to Newcastle line, particularly for settlements immediately north of the river in the Gosford region

On that line George Peat had received grants of land on both sides of the river, at Kangaroo and Mooney Points, and here he built a lugger to communicate with his holdings and then gain access south to the Sydney Markets. This offered a short cut for any Gosford traffic such that by 1845/47 Peat's lugger was being used as a ferry between Kangaroo and Mooney Points.

This service continued until superseded by the railway link via the 1889 Hawkesbury River Railway Bridge to the east at Brooklyn. It would be another 40 years before the ferry route was reopened for road traffic due to the increasing demand from motor vehicles in the 1920s.

In 1925 the Main Roads Board began to upgrade the road from Hornsby to Kangaroo Point and to Gosford on the north side of the river, soon to become known as the Pacific Highway. In 1930 two Government-run vehicular ferries (aptly named the *George Peat* and the *Frances Peat*) came into service.

The significance of this matter can be gauged by the twelve news items and photographs that appeared in the Sydney Morning Herald from 10 May to 6 August 1930.

However, plans were already being drawn up to build a permanent bridge. Site investigations and preliminary designs were commenced. From the experiences with the nearby railway bridges (the 1889 bridge was to be replaced) it was clear that the new road bridge would be a major works project.

In 1937, following heavy road traffic use of the ferry service, it was decided to proceed with the construction of a new high level bridge. Tenders were called in January 1938 and the successful tenderers were The Clyde Engineering Co. Ltd. for fabrication, and Balgue Constructions Co. for site constructions and bridge erection.

Work commenced in 1939 and was completed in 1945 with an official opening on 5th May.

Heritage Listings:

Currently, the Peats Ferry Bridge is only listed on Hornsby Council's Local Environment Plan, but the Roads and Traffic Authority is preparing an entry for its S170 Register followed by an entry on the State Heritage Inventory.

2. ASSESSMENT OF SIGNIFICANCE

Historic Phase: An historical site, dating back to the early colonial period of New South Wales, where George Peat used his lugger as a ferry in 1845/47, hence the geographical name of the site Peats Ferry and of the bridge 100 years later, Peats Ferry Bridge. The ferry provided a much needed short land route north to the Gosford region in competition to the oft-times hazardous sea transport. The combination of ferry and primitive tracks were the forerunners of the direct route from Sydney to Newcastle, the Pacific Highway, consolidated by road improvements in the 1930s and construction of a major bridge over the Hawkesbury River. It has become one of the most significant river crossings in New South Wales.

Historic Association: Design of the bridge was carried out by the engineering staff of the Department for Main Roads, in particular, a comprehensive preliminary report was prepared by H M Sherrard (future Commissioner 1953-62) in 1927; Spencer Dennis was Bridge Engineer from 1928 to 1951 and was associated with over 1,000 DMR bridges including Peats Ferry Bridge; Frank Laws joined the Main Roads Board in 1926 and was assistant bridge engineer to H M Sherrard on the Peats Ferry Bridge, retiring as DMR Chief Engineer in 1962; Vladimir Karmalsky was a brilliant engineer of the 'European School' who had come to Australia in time to join the Peats Ferry team, he was responsible for many innovative bridge designs.

The fabrication contractor was The Clyde Engineering Pty. Ltd, a leading heavy engineering company that had a long historical association with engineering, starting as Hudson Brothers at Clyde in the 1880s who built the temporary flume for Sydney's Water Supply in 1886. Railway rolling stock, locomotives and bridges were regular items of output. Their modern diesel locomotive plant is located at Kelso near Bathurst.

Creative or Technical Achievement: The Peats Ferry Bridge was a significant technical achievement from foundations to superstructure, a bridge to rival its more acclaimed neighbours, the Hawkesbury River Railway Bridges.

The one caisson pier was the second deepest in the world at 241ft (73.5m) below low water and considerable construction skill was required to salvage it when it 'ran' (sudden sinking through weak river-bed material) three times.

The choice of large steel K-trusses meant the truss members were larger than ready-rolled steel sections. The decision to fabricate the desired sections by welding was a landmark one, using technology that was state-of-the-art for its time when wartime applications of welding to Liberty ships had revealed faults and the contemporary Hawkesbury River railway bridge was an all-riveted structure.

The Peats Ferry Bridge trusses were the largest welded steel bridge elements in the world, and with the combination of DMR engineering, Clyde Engineering, Balgue Constructions and local materials, it was truly a remarkable all-Australian achievement.

Research Potential: The 1945 bridge represents a pinnacle in the evolution of large metal bridges in New South Wales, from girders to trusses from the 1880s to the 1950s (Sydney Harbour Bridge excepted). The juxtaposition at the site of 1973 welded steel box construction for the F5 bridge demonstrates the impact of new technologies at different times in history.

Aesthetics: The bridge sits prominently over the wide river crossing, a dominant, strong structure that conveys conquering stability. It is a handsome structure with "gateway" qualities – the northbound arrival at the river – the southbound arrival at the outskirts of Sydney.

Social: The bridge has provided enormous social benefits for the east coast of Australia, particularly to communication north of Sydney and to the Central Coast of NSW.

Rarity: It is the largest welded steel K-truss road bridge in Australia.

Representativeness: An excellent example of large steel truss bridge construction.

Integrity/Intactness: The bridge is original to its 1945 design with only minor attachments for service ducts and pipes.

References: *DMR = Department of Main Roads, NSW*

Author	**Title**
DMR	The Hawkesbury River Bridge *Commemorative Booklet 1944*
F Laws	Crossing the Hawkesbury River *Main Roads, v1, No3, pp 64-67, Dec 1929*
DMR	Welding off Steel Structures *Main Roads, vXI, No4, pp 112-114,Aug 1940*
DMR	*The Roadmakers, p32, p121, p188-189*

Statement of Significance: (summary of important items from the assessment)

The Peats Ferry Bridge has significance under the four principal heritage criteria
- Historical and Association, Technical, Social and Aesthetics.

1(a) **Historically** because the site was the first regular ferry service across the Hawkesbury River by George Peat in 1845/47. It was the forerunner of the direct northerly road to Newcastle, consolidated by the bridge as the Pacific Highway.

1(b) By **Association** with four eminent DMR bridge engineer (Sherrard, Dennis, Laws and Karmalsky) and historically significant Clyde Engineering Pty. Ltd.

2. **Technically** because the bridges trusses were the largest welded steel bridge works in the world and the main caisson pier was the second deepest in the world. Under wartime constraints, the design, fabrication, construction and supply of materials was a significant all-Australian technical achievement.

3. **Socially** because it is one of the most significant river crossings in NSW, bringing enormous social benefits to the east coast, particularly the development of the Central Coast region immediately north of Sydney.

4. **Aesthetically** because the bridge sits prominently over the wide river crossing, a dominant, strong structure. It is a handsome structure with "gateway" qualities.

Assessed Significance: **State**

Image with caption:

The 1945 Peats Ferry Bridge across the Hawkesbury River, NSW

Proposed Plaque Citation:

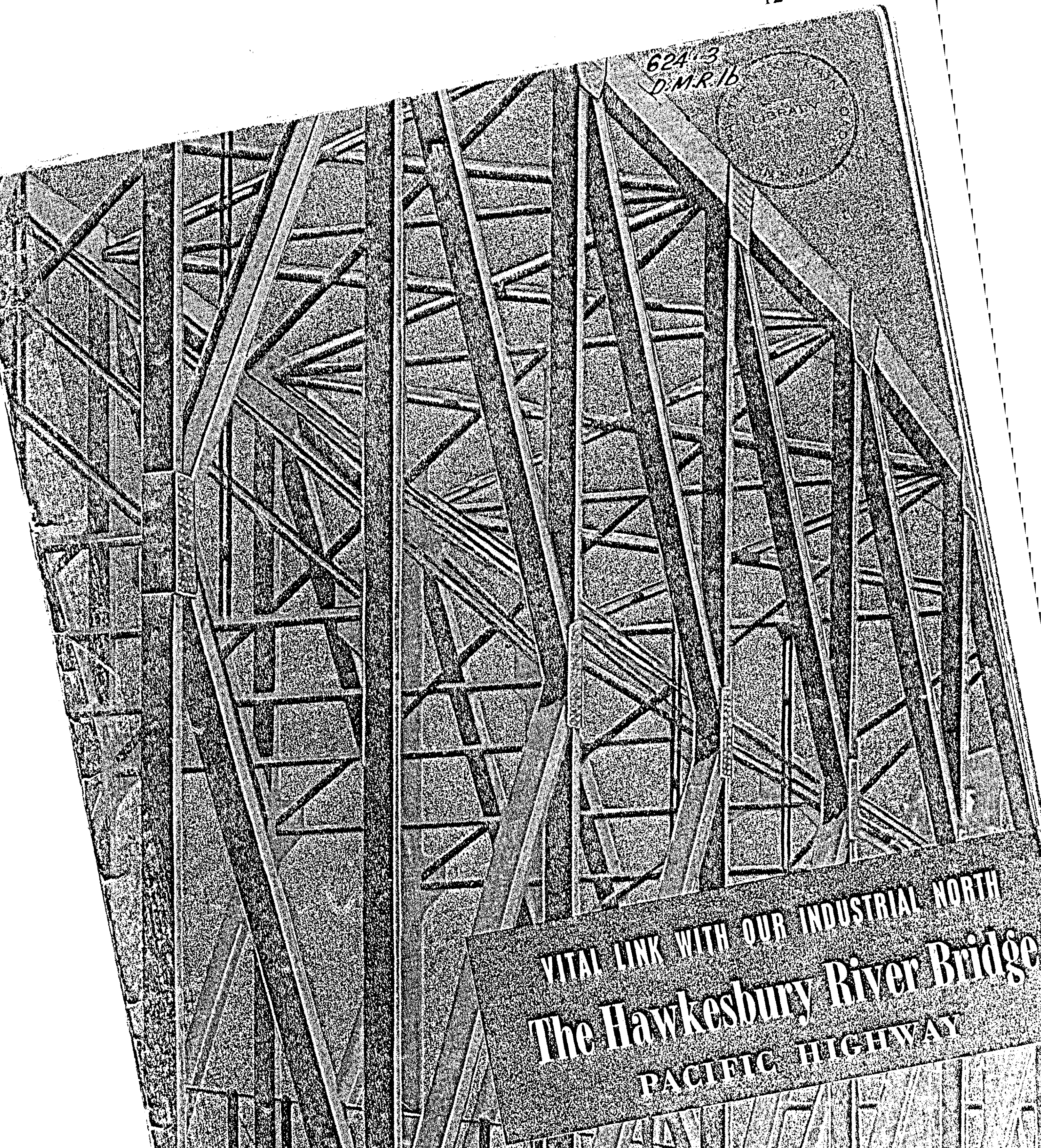
IEAust **HISTORIC ENGINEERING**
Logo **MARKER**

Peats Ferry Bridge

Opened on 5 May 1945, this bridge was designed and supervised by Department of Main Roads engineering staff, fabricated by Clyde Engineering and built by Balgue Constructions during wartime constraints, a significant local and technical achievement. The main caisson pier was the second deepest in the world and the steel trusses were the largest welded bridge works in the world. Its construction consolidated the direct coastal road, the Pacific Highway, north from Sydney and the development of the Central Coast Region. (83 words)

The Institution of Engineers Australia
Roads and Traffic Authority 2005

APPENDICES


VITAL LINK WITH OUR INDUSTRIAL NORTH
The Hawkesbury River Bridge
PACIFIC HIGHWAY

The Hawkesbury River Bridge

PACIFIC HIGHWAY

CONTENTS

Early History

THE selection and development of a direct route for road communication between Sydney and Newcastle can be traced back to the early days of settlement in Australia.

The Hunter River was discovered shortly after the arrival of the first fleet and a settlement was established at Newcastle in 1801.

For some years the only means of land communication between Sydney and the Hunter River Valley was that known as "Howes track", following approximately the route of the recently re-opened road from Windsor through Richmond, Putty and Bulga to Singleton.

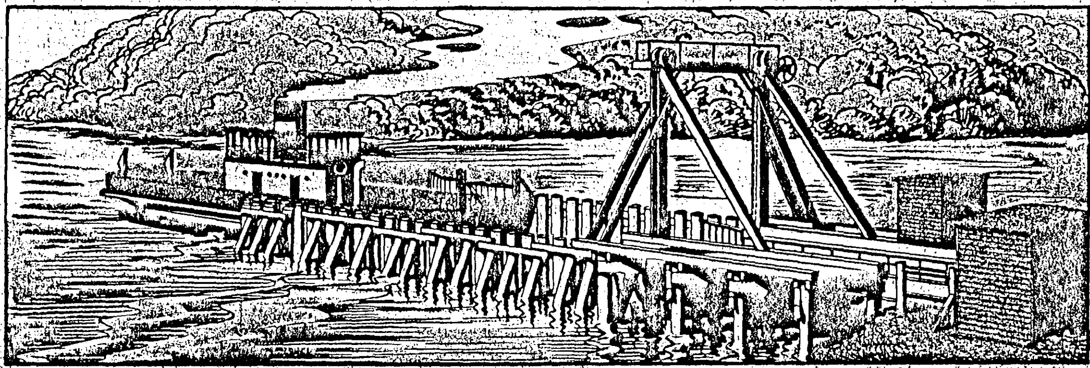
In 1830 the route via Wiseman's Ferry and Wollombi was opened to vehicular traffic and became the principal route for overland communication between Sydney and the Hunter River.

Shortly after the road via Wiseman's Ferry was opened up, George Peat, a ship builder, obtained grants of land on either side of the Hawkesbury River at Kangaroo Point and Mooney Point, which he devoted to grazing. To send his cattle to market he built on the river bank a two masted sailing lugger for use between the two points.

The presence of Peat's boat acted as an encouragement to travellers to use this short cut as an alternative to the Wiseman's Ferry Crossing. It was also used by travellers between Sydney and Brisbane Water and by 1845 the lugger was in use as a ferry between Mooney Point and Kangaroo Point.

For the next 44 years, until the opening of the through railway communication between Sydney and Newcastle in 1889, resulting in the cessation of Peat's Ferry, there were available, therefore, two roads to the North, one via Wiseman's Ferry and the other via Peat's Ferry. Of these, however, the former was superior and the one chiefly used.

The Hawkesbury River Railway Bridge completed in 1889 had an adverse effect on road traffic to the north and it was not until the advent of motor vehicles that a demand arose from the various local governing bodies concerned for the opening up of direct road access between Sydney and Newcastle by the construction of a suitable road between



Berowra and Gosford. Agitation for this road continued from 1913 to 1921, at which time, owing to the rapid growth of motor vehicle registrations which was taking place and the conditions of the roads, the demand for a considerable improvement in the main roads of the State became insistent. The Government of the day commenced the system of giving assistance towards the improvement of main roads and this culminated in the passing of the Main Roads Act of N.S.W. in 1924. It is not surprising that one of the first requests received by the Main Roads Board, appointed in 1925, was to provide satisfactory road connection between Sydney and Newcastle.

Considerable investigation of the already existing routes and suggested routes, with comparisons of relative costs and benefits accruing, was carried out before determining on the re-establishment of the Peat's Ferry crossing and the replacement by a modern road of the Old Peat's Ferry Road.

While there existed plenty of scope for improvement in the existing route between Gosford and Newcastle, no portion of the country could be described as difficult. The main problem associated with the general route was, therefore, the length between Sydney and Gosford. As there was a usable crossing of the Hawkesbury at Peat's Ferry it was clear that, provided the road between Sydney and that crossing could be made into a suitable road, great advantages would follow if it could be linked up with Gosford. Sydney and Newcastle would then be connected by a direct road, shorter by approximately fifty miles than any other route. This saving in distance between the two chief cities of the State, apart from its economies in initial cost of construction and subsequent maintenance would at once effect large savings in vehicle operating expenses which would also automatically increase with growth of traffic. Further, because of the high value of these savings, large expenditure would, if necessary, be justified to secure them.

The engineering difficulties of establishing this route were apparent; the broad waters of the Hawkesbury and the rugged sandstone ranges on either side had always constituted formidable barriers. The outstanding merits of the Kangaroo Point — Mooney Point crossing and its suitability for either a high level or low level bridge or ferry crossing were confirmed in May, 1925. Two months later instructions were issued by the Main Roads Board for reconnaissance surveys to be undertaken on both the southern and northern sides of the Hawkesbury with the objective of establishing a two-way traffic road carrying a 20′ width of pavement. It had to be located, so that, should it become necessary in the future, a total width of 40′ could be obtained.

The reports on the survey indicated that these objectives were possible. Work was commenced almost immediately on both the southern and northern sides of the river and completed in 1930.

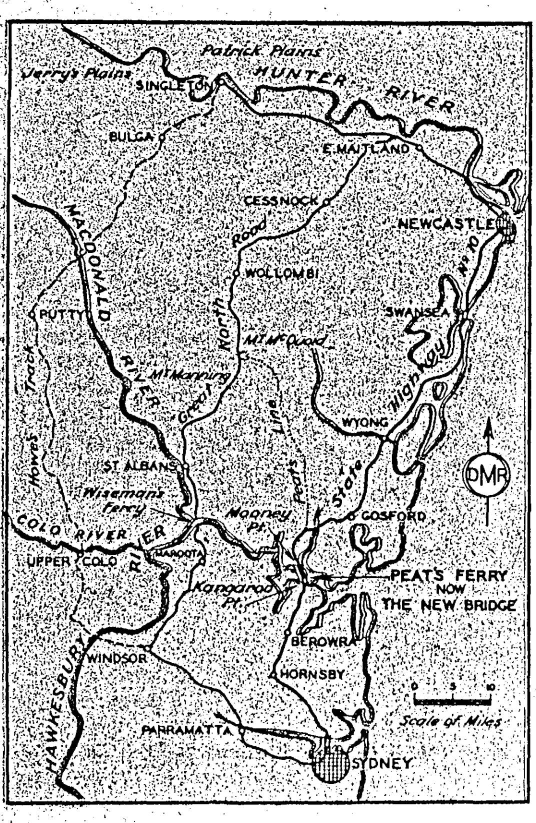
CROSSING THE HAWKESBURY RIVER.

The first steps towards determining the means to be adopted for crossing the Hawkesbury River were taken in 1925. A trigonometrical survey was made to establish the distance between two fixed marks on Kangaroo Point

and Mooney Point respectively and on an approximate line to suit a high level bridge. This survey showed that the distance between Kangaroo Point and Mooney Point was 2,600′ at its narrowest point — the shortest possible distance anywhere near the vicinity.

Preliminary borings taken during 1927 showed rock inaccessible down to depths between 170′ and 208′ for the southern half of the crossing, and available at depths from 102′ to 155′ for the northern half of the crossing. Soundings of the river bed were also taken and on this and other data a report was prepared covering four possible means of providing for the crossing; these were as follows:—

1. Low level bridge partly on pontoons.
2. Low level steel bridge with opening span.
3. High level bridge.
4. Ferry Service.



It was decided to build a high level bridge. Its immediate construction was not financially practicable, however, and the cheaper ferry service was therefore installed.

Difficult conditions of wind, weather and tide had a particular bearing on the selection of ferry dock sites, and the final positions decided upon were also chosen to eliminate dredging as much as possible. When docks were ready one ferry was despatched to the site and commenced operating the service on 25th May, 1930.

Two ferry vessels for the service were built in Sydney and were named the "George Peat" and "Frances Peat" after the owner of the first ferry and his wife. They were diesel powered, each with a deck space sufficient to accommodate 37 motor vehicles of average size, and with covered seating accommodation on an upper deck for 20 foot passengers.

These vessels were in operation for some years, but have now been impressed for war service in the north. They have been temporarily replaced by the only vehicular ferry vessel available, the reserve ship from the Newcastle - Stockton service, the "s.s. Mildred".

When installing the ferry service care was taken to reserve necessary land adjacent to the river for both the approaches to the ferry and ultimately a bridge; the ferry dock and the approaches were so located that the ferry service could be carried on without interfering with the construction of a bridge and its approaches.

In 1937, following increase in traffic using the road, it was decided to proceed with the construction of a high level bridge. Alternative designs, one incorporating cantilever spans and the other two simple truss spans, were prepared and tenders invited in January, 1938.

The design actually adopted was that prepared by the Department, which also supervised the project.

The successful tenderers were The Clyde Engineering Co. Ltd for the supply and fabrication of the superstructure, and the Balgue Constructions Co. for the erection of the bridge, their tenders being based on the design incorporating the truss spans.

Design by Main Roads Department

Design of the bridge incorporated two exceptional features : (a) Substitution of welding for riveting in the fabrication of all members in the two main truss spans, each 440 ft. long. (b) A very deep "caisson" type which ultimately reached a depth of 241 ft. 4 in. below low water level — believed to be the second deepest in the world.

IN selecting the site for the bridge structure the main consideration apart from the uncertain nature of the material in the bed of the river was the necessity to utilise as far as possible the roads already constructed on both sides of the river. Provision had also to be made for continuous use of the existing ferry docks. The bank on the south side is very steep and rocky, with the deep portion of the river adjacent to it. On the north side the river is shallow for a considerable distance from the bank with mud flats exposed at low tide and the bank itself at the site finally selected is gently sloping.

At this site, the width of the river at low tide is 2,600 ft., but the construction of an embankment of rock fill on the mud flats on the north side reduced the length actually to be bridged to 1,990 ft. This is not the longest road bridge in New South Wales or in Australia. Longer ones are the Hornibrook Highway in Queensland (about 8,000 ft.) and at Gundagai in New South Wales (3,030 ft.).

Borings were taken to depths of up to 200 ft. and disclosed mud, shells, sand and clay, but it is difficult to obtain a true sample of material at such depths, and the exact condition of the various strata at these depths cannot be accurately determined. In the absence of rock in the bed of the river at a reasonable depth it was obvious that costly and difficult pier construction could not be avoided, especially at the south side. On the north side inexpensive short spans supported on piles were practicable as the water is shallow and the mud and sand suitable for pile driving. As the water deepened this simple construction could not be used and piers of increased size were necessary, though still on piles driven in groups. Consequently longer spans were used so that fewer of these larger piers would be required. These spans are 90 ft. long of the steel plate girder type.

Over the deeper portions of the river pile supported piers became uneconomical and it was necessary to resort to very long spans with as few piers as possible. It will be realised that the longer spans entail very heavy steel work and the increased cost of this construction is compensated for by the reduction in the number of piers. The final choice as the most suitable design for this portion of the bridge was for two truss spans each 440 ft. with only one pier, and that of the "caisson" type, which is built by open dredging.

Plans were prepared based on this design and on an alternative design for a "cantilever" bridge with spans 188 ft., 564 ft. and 188 ft. Further, when tenders were called, firms tendering were asked to submit tenders for designs prepared by themselves. Tenders were received for these various alternatives but the most favourable was that for the two long truss spans.

In order to meet the requirements of navigation, a clearance of 40 ft. above water level has been provided over the deep water in mid stream but has been reduced on the northern side by grading the deck of the bridge down towards the north and thus reducing the cost of the embankment. The width of the bridge was fixed after consideration of the traffic requirements, the 30 ft. adopted providing for three lanes of traffic, while a footway 6 ft. wide is provided on the upstream side. The structure was designed to carry safely in each of the three lanes of road traffic a heavy vehicle, of 40,000 lbs. weight on two axles, and a uniform load of 70 to 100 lbs. per sq. ft. over the balance of the area in front and behind the heavy load to allow for smaller vehicles. On the footway provision was made for a load of 70 to 80 lbs. per sq. ft. The total live load which one of the main spans was designed to support is about 600 tons.

Extensive investigation was undertaken to determine the most suitable type of truss span. From the Department's experience of welded construction in smaller bridges, it was considered that welding of the various portions of the members could readily be extended to the heavier type of bridge proposed, and the

results achieved justify the decision. These trusses are believed to be the longest in the world where welding has been used throughout the fabrication in the shop. For the connection of the members at the site to form the completed truss, the conventional method of riveting was adopted.

The trusses are "through" trusses with a top chord on a series of straights to make the section more economical and to provide a pleasing appearance. The type of bracing adopted is that known as the "K" system which is most appropriate for this length of span and depth of truss and results in comparatively short members with a further advantage of reduction in "secondary" stresses. The heaviest parts of a truss bridge are usually the sloping members at the ends, which in this bridge consist of two side plates 2 in. thick and 2 ft. 6 in. deep, with a web plate 1½ in. thick and 12 in. wide joined by continuous welded seams to the side plates, the whole forming in cross section a letter "H". This "H" type of section is used generally for the top chord, the web verticals and diagonals. The lower chord or horizontal member at the bottom of the truss consists of side plates of varying thicknesses up to 1¾ in. and a top plate ⅞ in. thick, with smaller plates at the bottom giving a section of the shape of an inverted "U". The top and bottom chords are connected together with light lateral bracing for stiffening against uneven loading and side loads from wind.

The expansion bearings under the trusses to allow for movement due to temperature variations are of interest; the whole four having semi-spherical tops which fit into hollow castings bolted to the underside of the truss. Three of these bearings are free to move longitudinally with the bridge structure, while the fourth is fixed to the top of the pier.

The 90 ft. plate girder spans are of normal type except that welding was used in their fabrication and heavy plates up to 2 in. thick were used for flanges with butt welds where required. The girders, two of which are required per span are 7 ft. 3½ in. deep and were brought to the site from the fabricating works ready for erection. These spans also rest on cast steel bearings with spherical tops, but two in each span are fixed and two are free to move. The eight smaller spans on the northern end are each 40 ft. in length and consist of ordinary rolled steel joists.

The deck of the bridge is of reinforced conrete resting on steel stringers and is covered with 2 in. of bituminous concrete.

In the design of the piers there are many unusual features. Piers other than No 1 and No. 2 are supported on reinforced concrete piles of exceptional size. These piles are of solid concrete 22 in. square for the short 40 ft. spans where considerable length is unsupported and 20 in. square for the other piers where they are wholly underground and with lengths up to 120 ft., reinforced with eight steel bars 1¼ in. diameter and weighing up to 24 tons each. They were designed to be lifted at certain points only.

These piles were used for the smaller piers by driving to a suitable depth and, after cutting the tops to the proper line, joining them with a reinforced concrete headstock to support the superstructure.

The piers supporting the plate girder spans were designed as two columns placed on a large concrete slab below the bed of the river supported by 21 piles. The largest of these piers which supports one end of the northern truss span, has 72 piles and was of such a size and type that special consideration had to be given to all details of construction before the design was completed. These details are described later.

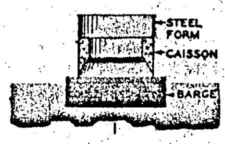
Similarly, in the design for the largest pier of all (No. 2) the methods of construction and sinking had to be known in advance and the design prepared accordingly. This pier is of caisson type and relies for its support on its large base area resting on suitable material assisted by frictional grip of the outer walls in the overlying material. The pier is 23 ft. wide and 51 ft. long with semi-circular ends, the side walls are connected by three transverse walls dividing the interior into four spaces or "wells".

The construction of this pier is shown in diagrammatic form in the sketches on opposite page.

STAGES IN CONSTRUCTION OF THE WORLD'S SECOND DEEPEST BRIDGE FOUNDATION.

1. *FIRST SECTION WITH FALSE BOTTOM.*

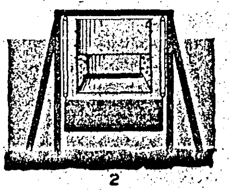
The first section of the caisson which was constructed on a barge and fitted with a false bottom and with a steel extension upwards which was used for the outside formwork for the future extension in concrete and also to provide additional buoyancy for the floating portion.



1

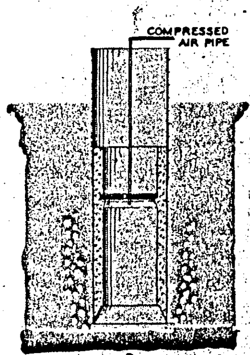
2. *FLOATING CAISSON.*

The barge at the launching dock which has been scuttled by filling with water and by pulling down to such a depth as to allow the concrete caisson to float and be towed to one side, when the barge is then allowed to come to the surface and be removed.


2

3. *BUILDING UP AND LOCATING CAISSON.*

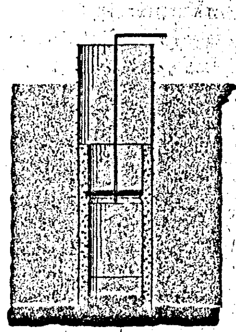
The caisson located at its correct position after building up to a suitable height with a further temporary bulkhead added. Between this bulkhead and the original false bottom air pressure was applied to enable the original false bottom to be forced off and drawn clear before the caisson reached the bottom of the river.



3

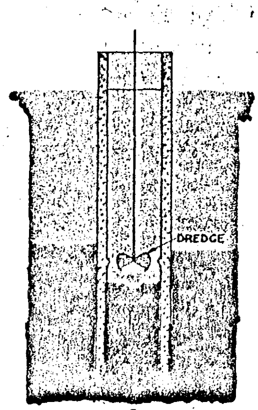
4. *"LANDING" CAISSON.*

The caisson resting on the river bed. This portion of the work was effected by reducing the air pressure below the temporary bulkhead, thus reducing its buoyancy. As soon as the caisson reached the bottom the whole of the air was allowed to escape and the bulkhead was then removed.


4

5. *DREDGING OUT CAISSON.*

The subsequent sinking process. On the removal of the bulkhead as mentioned in (4), the caisson filled with water and further sinking was effected by dredging out the mud inside. As the concrete was built up increasing the pressure, the caisson sank and further sections were built from time to time on top.



5

Fabrication of Superstructure

The contract for the manufacture, supply and delivery of the whole of the metal work of the superstructure of the bridge was let to The Clyde Engineering Co. Limited, Granville, New South Wales, for the sum of £94,797.

IT was a provision of the contract that the steelwork be temporarily erected in the works of the Clyde Engineering Company before being despatched to the site at the Hawkesbury River.

It is essential that work constructed under such conditions shall be of first-class quality and that the greatest accuracy must be observed to ensure that all parts will fit properly together on final erection.

A rigid specification was laid down for the welding of the superstructure to eliminate distortion and minimise contraction. The Company had to satisfy the Engineer of the Department of Main Roads, New South Wales that the officer in charge of the immediate and continuous supervision of the welding processes had had suitable training and practical experience in the execution of this form of construction and, further, that, before commencing work, each welder was required to make a test piece of welding in a form and of the dimensions laid down by the Engineer. The specimen piece of welding, upon being tested to destruction, was required to have an ultimate strength of not less than four (4) tons per inch of weld. This called for the utmost efficiency in all processes of welding.

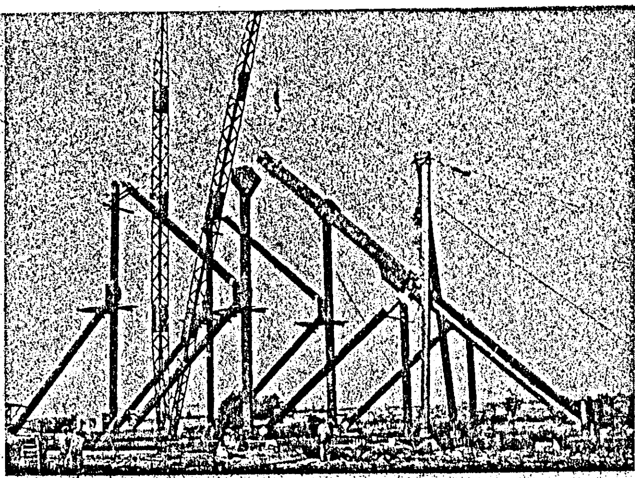
In addition to developing a special welding procedure, the handling of the parts making up a structure of the size of the bridge presented many problems.

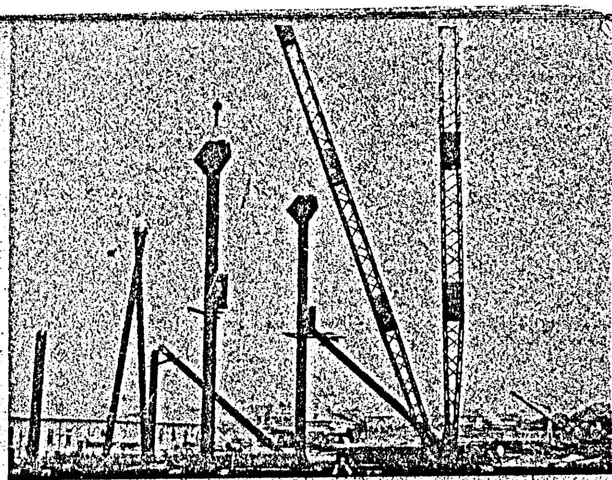
The Clyde Engineering Co. Ltd. designed and built special hydraulic riveting machines to enable the work of fabrication to be carried out efficiently. Special handling gear was manufactured to remove the parts from the various workshops to the site of temporary erection. Foundations were laid on the Works to carry the various sections of the bridge and a 10 ton Guy Derrick Crane was designed and built for the temporary erection of the structure.

Each section was subjected to final test and survey by engineers of the Department of Main Roads, New South Wales. It is no small tribute to the contractors — The Clyde Engineering Co. Limited — that the whole of the work was found to be in accordance with the specification in all respects, particularly when taking into consideration that the two Truss Spans were each of 440 ft. in length. After the work had been passed by the Engineer and before it was dismantled, each part was carefully marked to facilitate its erection on the site.*

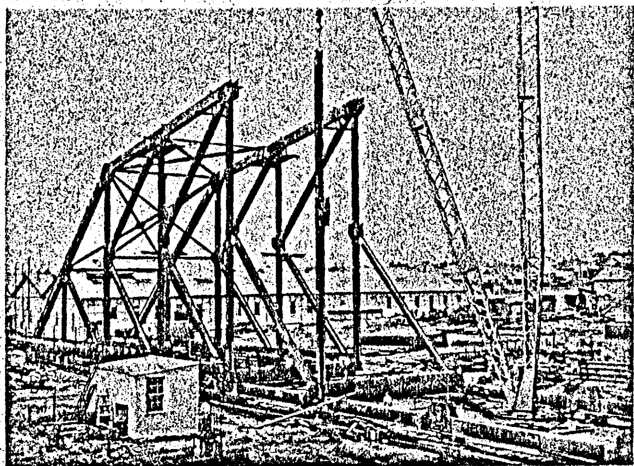
All sections of the superstructure were transported by road from the works of The Clyde Engineering Co. Limited to the site at Hawkesbury River by Messrs. A. Pittman Pty. Limited in units, the largest of which was 82 ft. long and 24 tons in weight.

** The storage space, handling and details of fabrication on the Works of The Clyde Engineering Company Limited can easily be imagined when taking into consideration that the weight of the structure was 2,180 tons.*

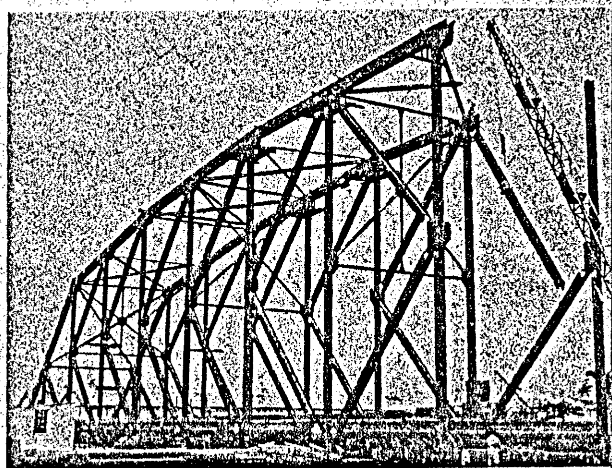




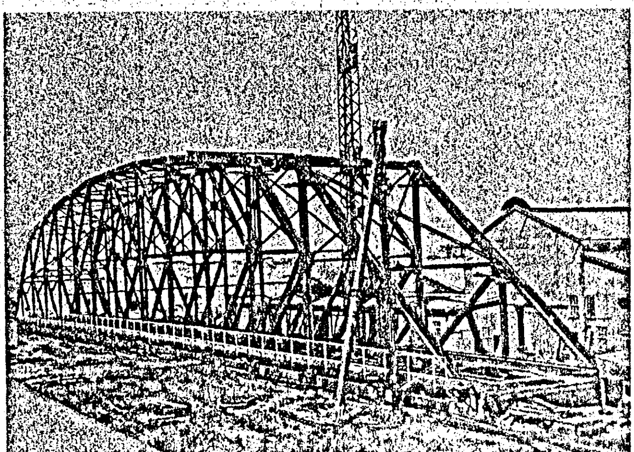
Early stages showing erection of web members.



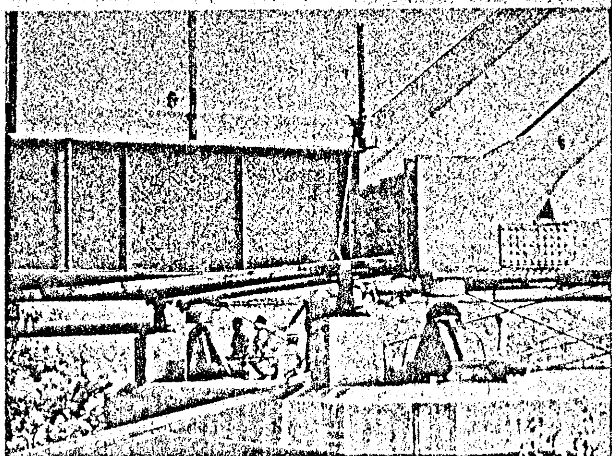
LEFT. *One-third of span completed.*



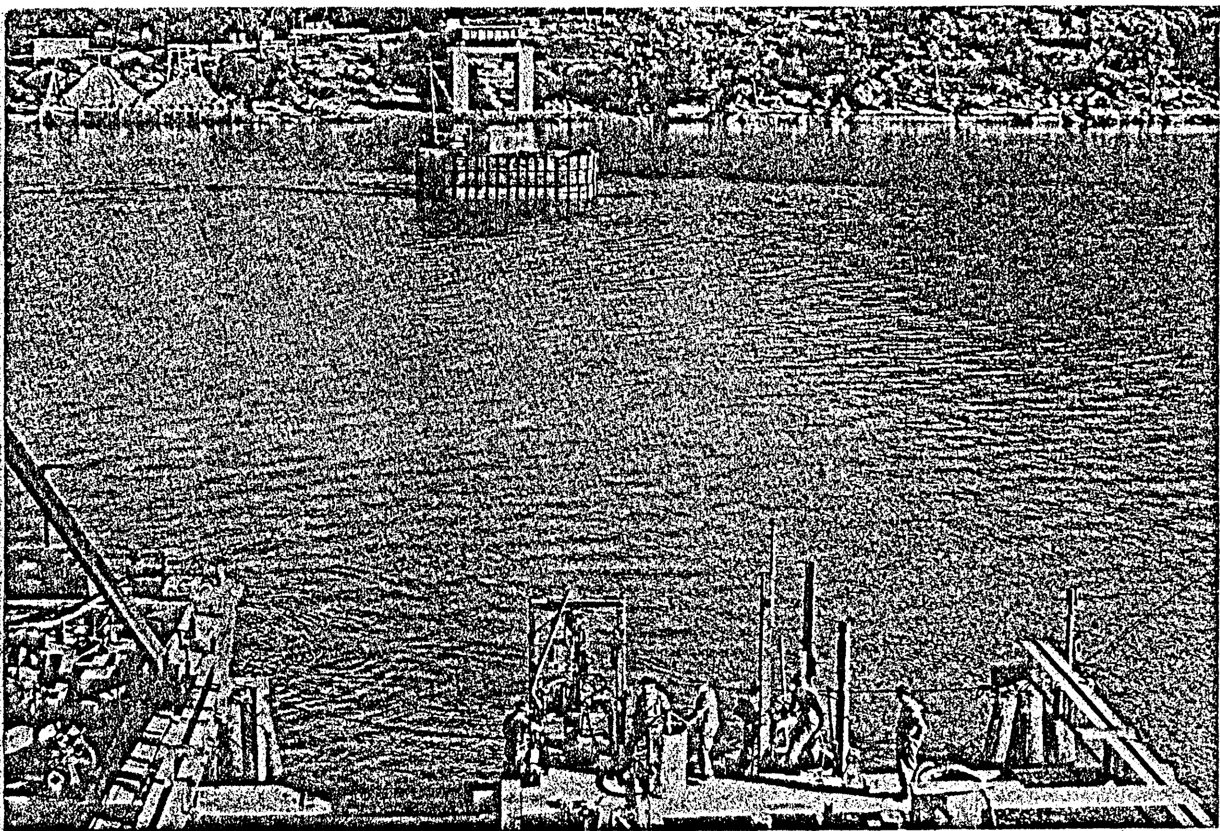
RIGHT. *Two-thirds of span completed.*



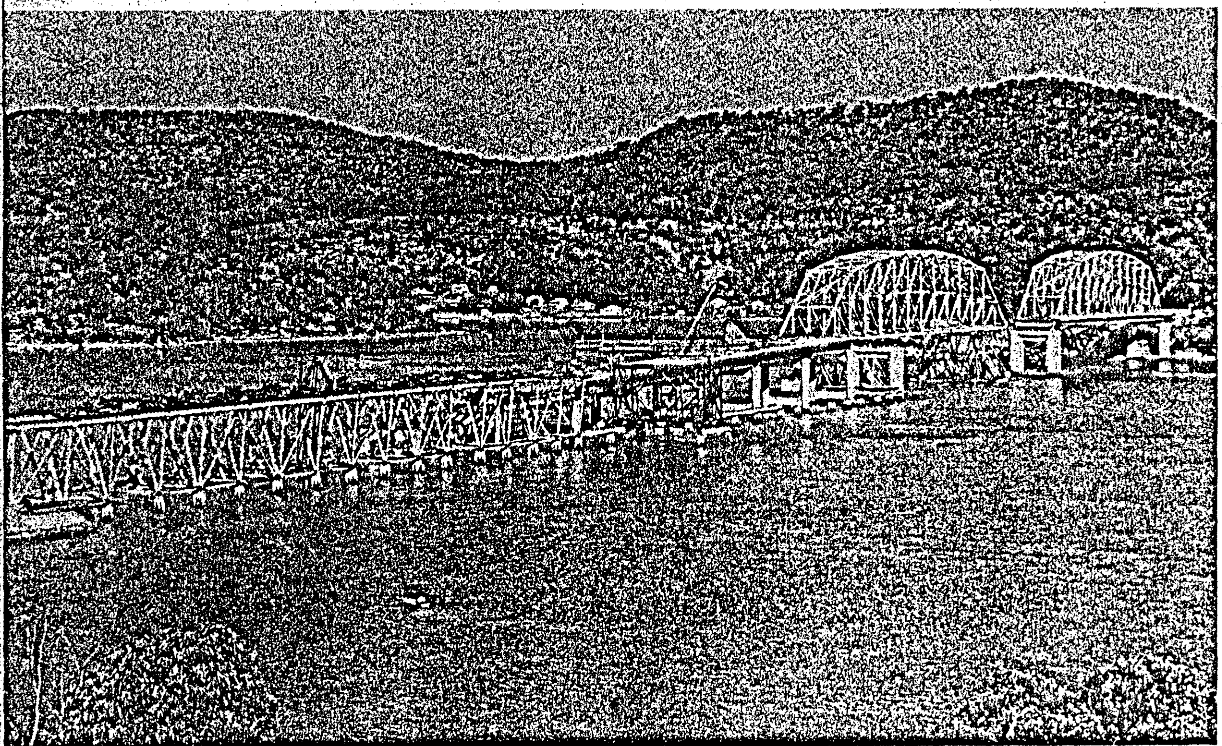
LEFT. *Span completely erected.*



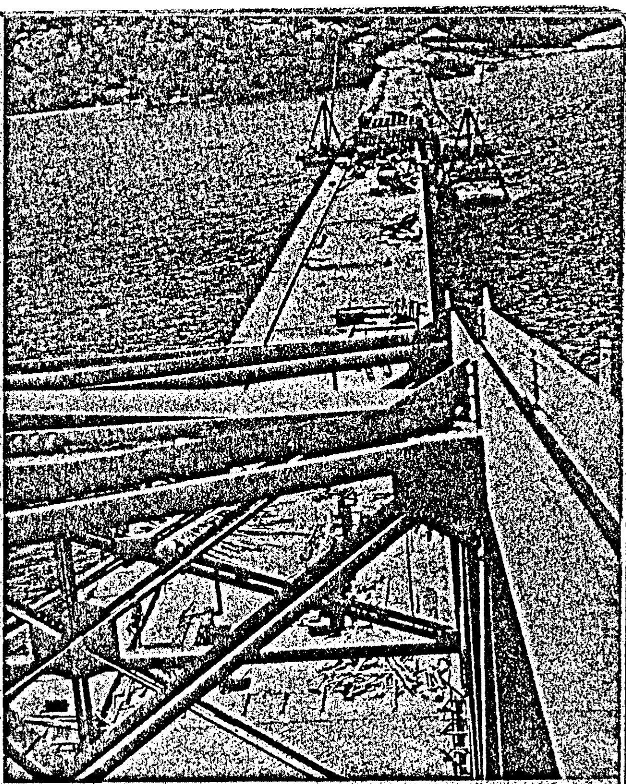
RIGHT. *Pier 1 with end portion of truss span about to rest on bearing.*



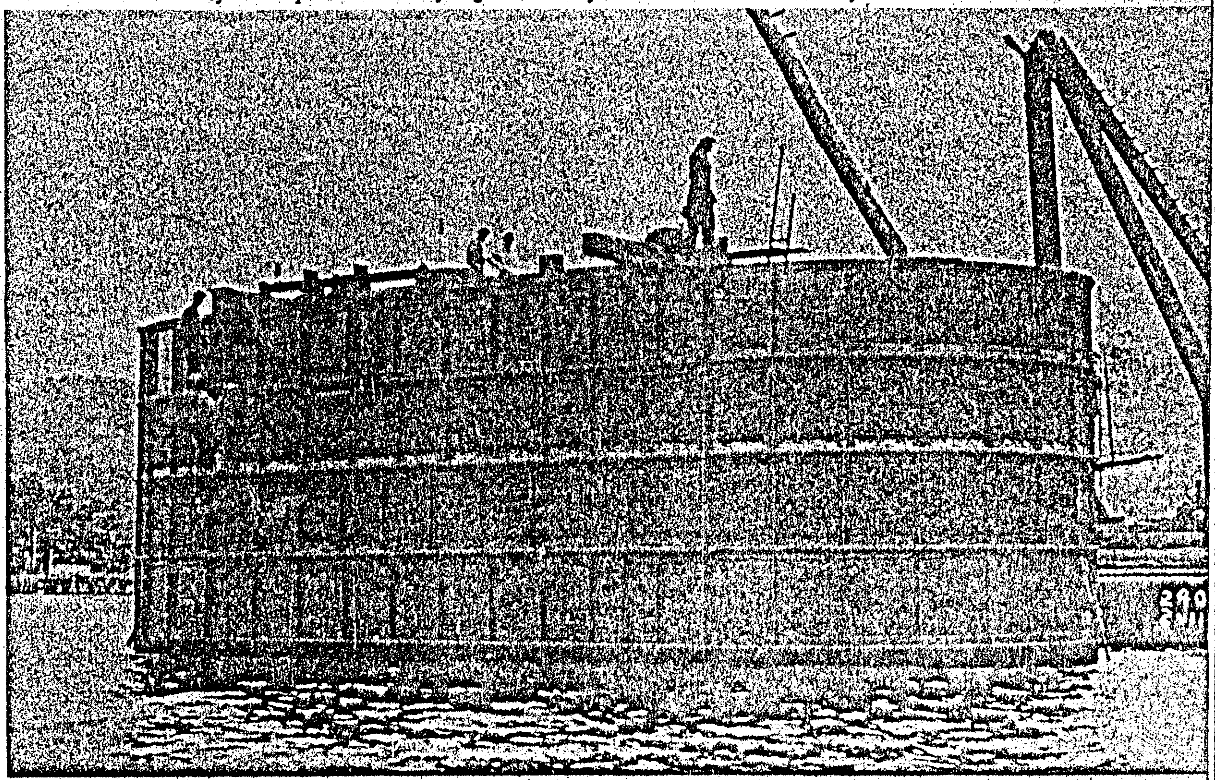
Pouring concrete at Pier 3. Pier 2 Caisson is seen in distance, Pier 1 and abutment at rear. Concrete materials at left.



General view showing "floating-in" of Span No. 3. In foreground will be seen falsework on which trusses were built.

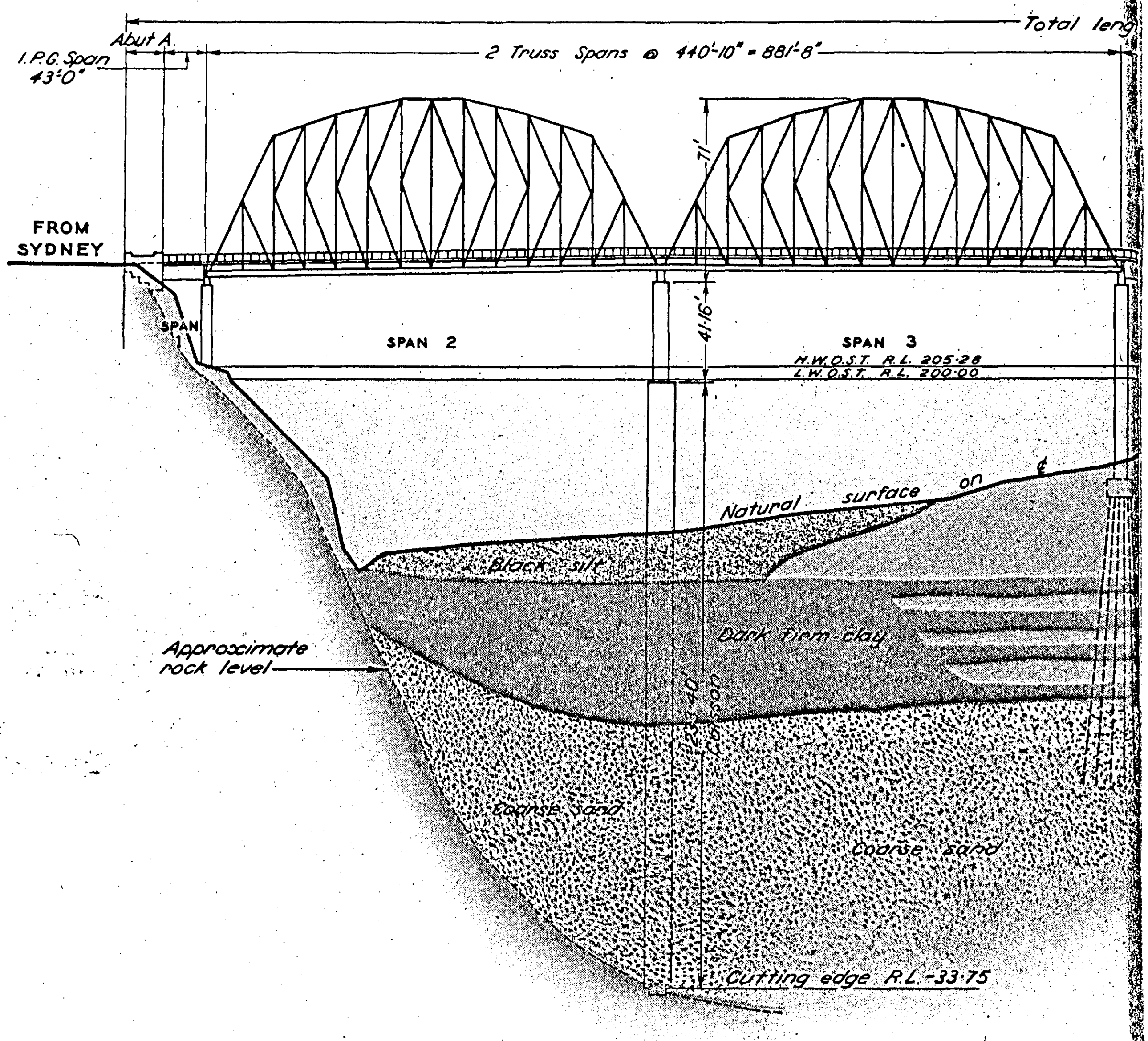



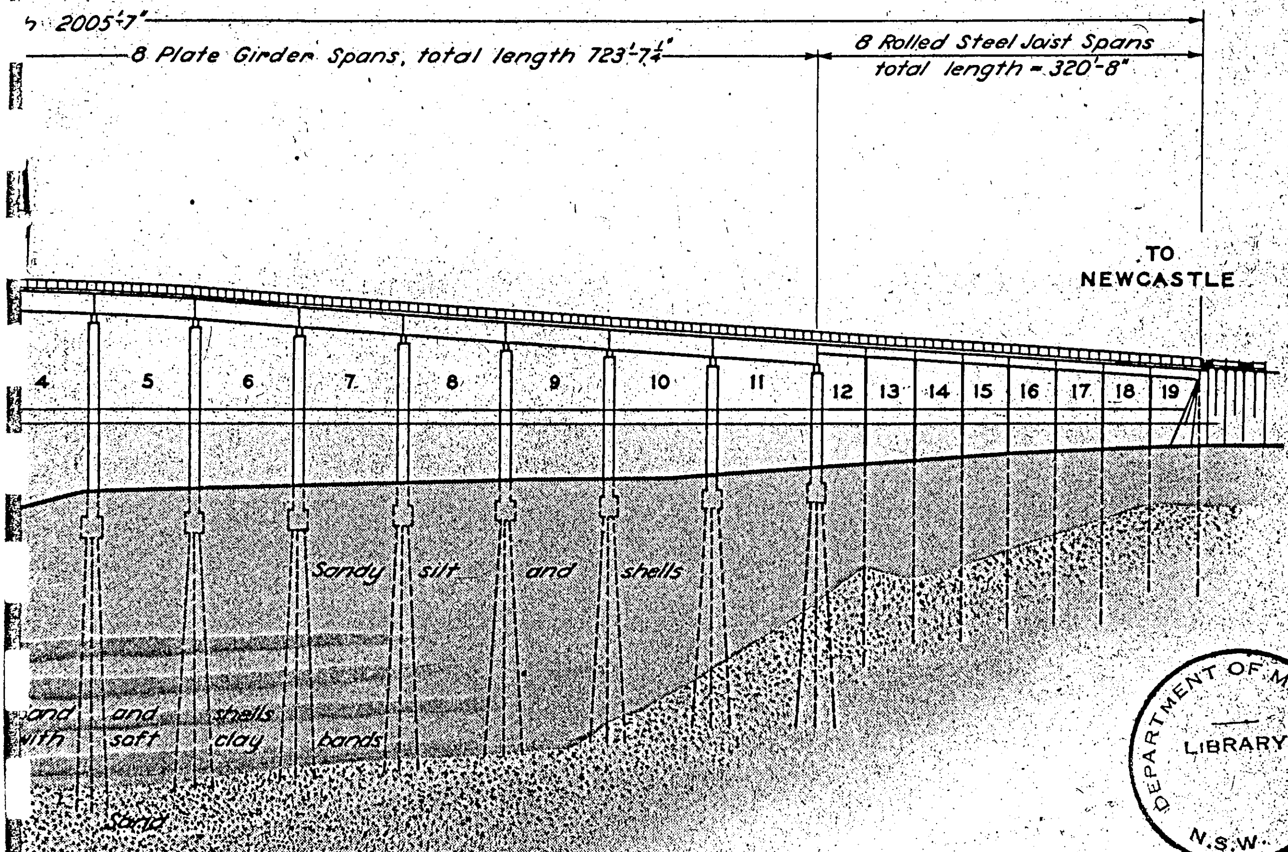
LEFT. *Dropping "bombs" with lighted fuse through 200 feet of water to clear away rock below caisson of Pier 2. The pipe guides the "bomb" to the required spot.* RIGHT. *Northern approach spans and embankment from top of truss span. Deck in foreground ready to receive bituminous surface.*



Pier 2 : Steel coffer dam used as outside form. Excavating by grab in process.

THE HAWKESBURY RIVER BRIDGE





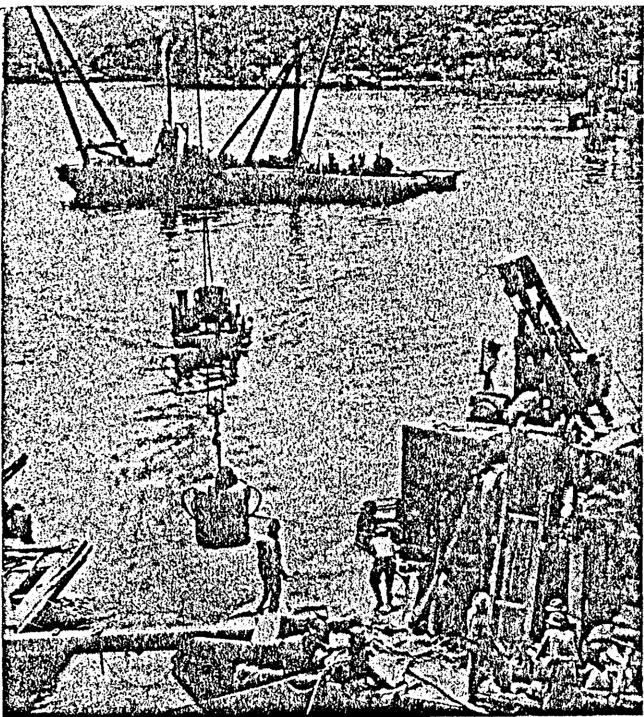
DIAGRAMMATIC ELEVATION OF BRIDGE

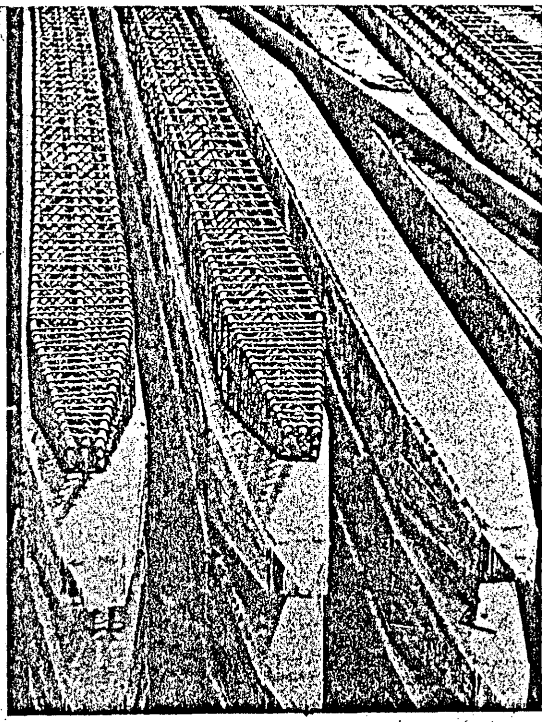
SHOWING THE MAIN DIMENSIONS
AND GENERAL NATURE OF FOUNDATION CONDITIONS
AS DISCLOSED BY BORING

NOTE: *In this sketch all vertical dimensions have been drawn two and a half times their true size.*

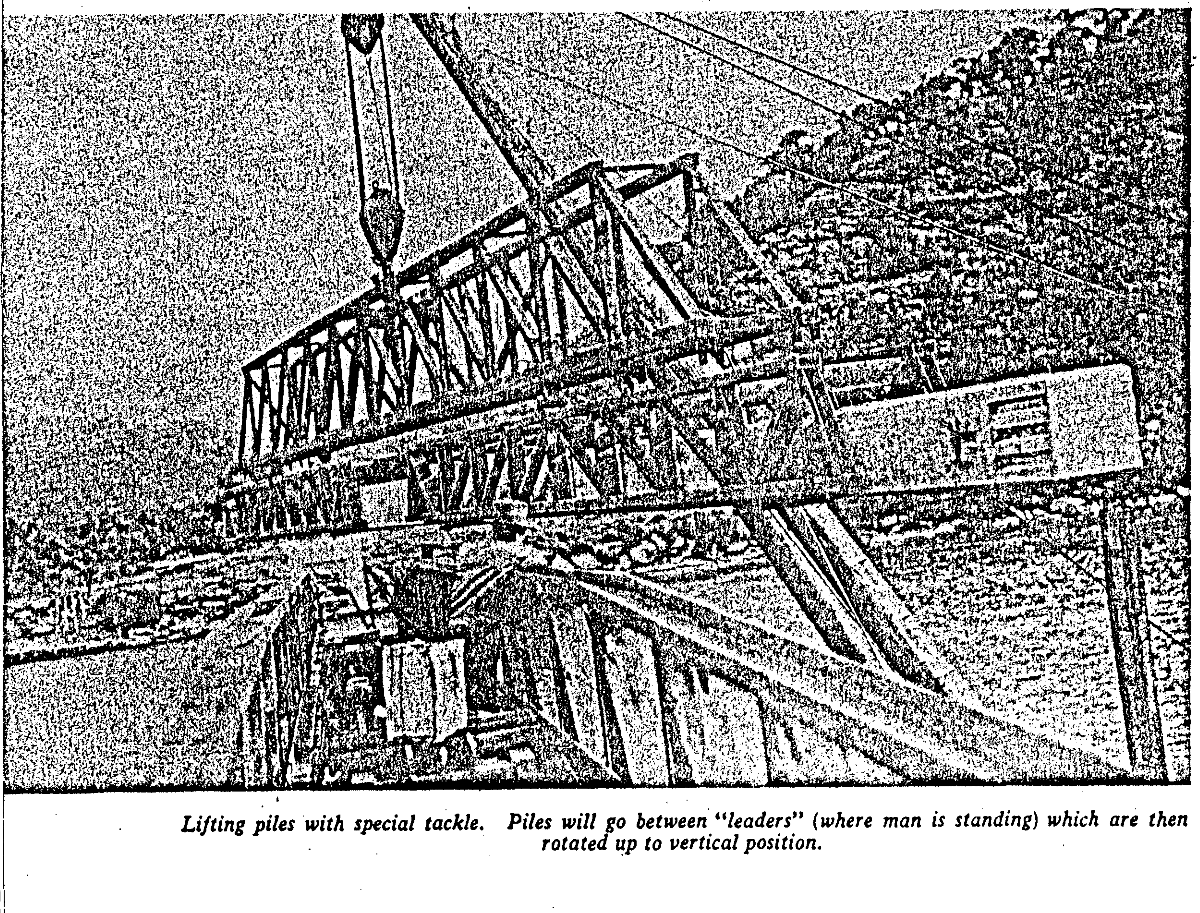
THE MATERIALS USED WERE:-

Structural Steel	*2000 tons.*
Reinforcing Steel	*1040 tons*
Concrete (all types)	*13,067 cub. yards.*
Cement	*4000 tons (96,000 bags)*
Concrete Piles	*23,681 feet. (approx. 4½ miles)*

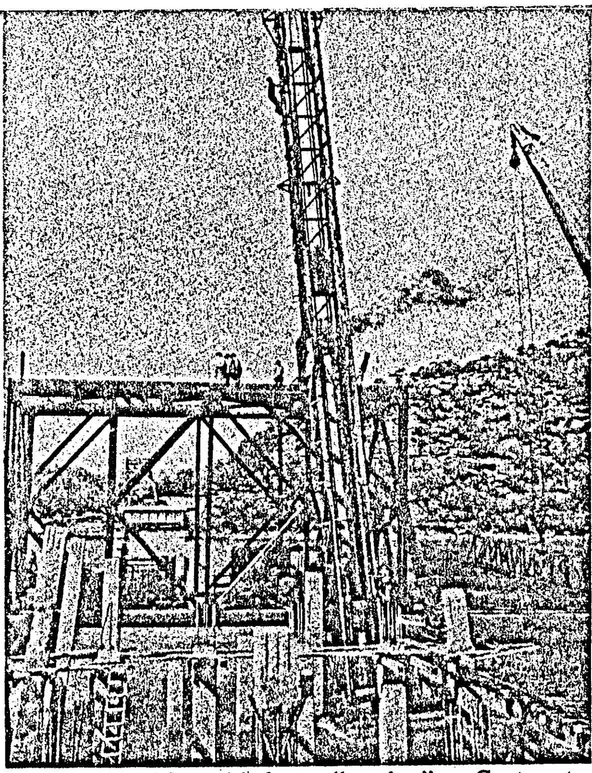


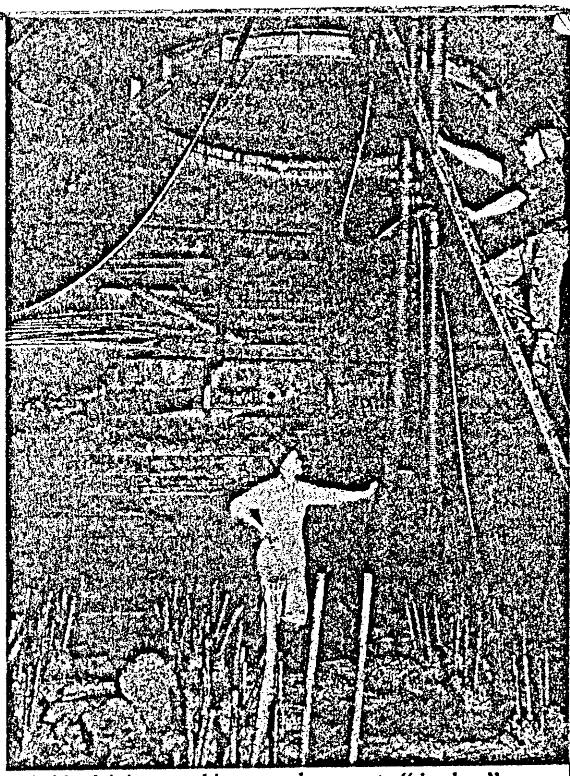


LEFT. *Concreting the seal over 200 feet below water at Pier 2 (far side of punt) using special buckets taken to pier on small barge.* RIGHT. *Reinforcement for piles and finished piles awaiting delivery by barge to the bridge.*

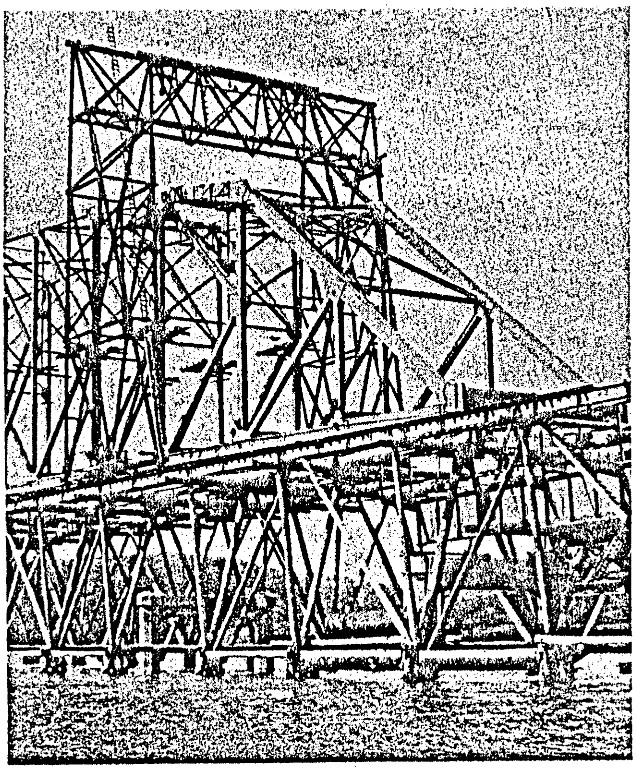


Lifting piles with special tackle. Piles will go between "leaders" (where man is standing) which are then rotated up to vertical position.

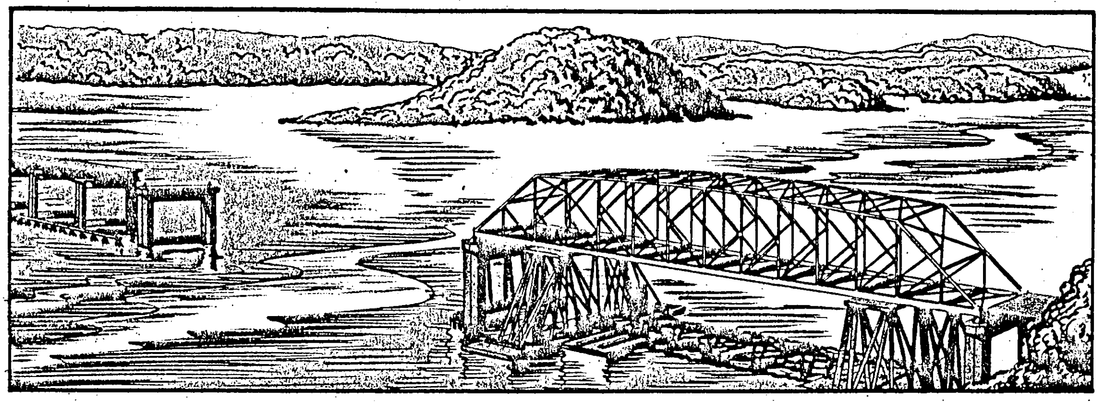




LEFT. *Pile driving with* 8 *ton "monkey". Gantry at rear holds driving machinery and supports "leaders".*
RIGHT. *Pier* 3, *inside "diving bell"* 50 *feet below water level. Tops of piles cut back leaving steel to bond with pier supporting slab.*



LEFT. *Truss with erection gantry being assembled on falsework. Below is small pier which will support approach span later.* RIGHT. *Span cup bearing coming over spherical support during last stage of floating-in. Plate girder span and rocker bearing at left.*



Construction—Methods and Equipment

The contract for the construction of the substructure and the erection of the superstructure of the bridge was let to Balgue Constructions Pty. Ltd. for £247,000.

THE construction of the substructure presented the major problem to the contractor. Several different forms of substructure were provided for in the plans, namely:

(a) Abutment A was founded on rock in the dry.

(b) Pier 1 was founded on rock, but below Low Water Level.

(c) Pier 2 was an open dredged concrete concrete caisson.

(d) Piers 3 to 11 were founded below mud level on nests of reinforced concrete piles.

(e) Piers 12 to 18 and Abutment B were reinforced concrete pile trestles.

Each type called for methods and equipment suitable for the job, and presented its own particular problems.

PLANT AND MATERIALS.

To tackle a job of this size and nature, special plant was necessary, and the contractor was faced with the necessity for building a considerable quantity of plant before any construction work could be put in hand. Two large punts 100 ft. x 30 ft. x 9 ft., of 400 tons carrying capacity were built and launched. One of these was equipped as a heavy lifting unit, with timber sheer legs capable of lifting 35 tons at a distance of 30 ft. from the nose of the punt, as well as having a drift of 60 ft. above water level. This punt also had a 4 ton revolving crane on it. The other big punt was equipped with a complete concrete mixing plant, with storage capacity for pouring 120 cubic yards concrete.

Other items of floating plant were two 4 ton revolving jib cranes on punts, several flat punts for transporting material, a tug, launches etc. All major items of plant were steam driven, but petrol engines were used for pumps, compressors, welding plant, etc.

The ground space available for stacking bridge steel, manufacturing reinforced concrete piles, assembling formwork and generally handling materials was very limited, owing to the rugged nature of the adjacent country. A small flat on the Sydney side

about $\frac{1}{4}$ mile from the bridge abutment, through which a creek ran, was developed into a stacking and handling ground. The creek was dredged out and retaining walls of timber sheeting driven to form a canal into which the material punts could enter. A timber overhead travelling gantry capable of lifting 30 tons, with a span of 130 ft., and clearance of 19 ft. above ground level was erected, and commanded an area of about 300 ft. x 130 ft., with the canal in the centre. This space was accessible by road from either side of the canal; and materials brought in by road were unloaded and stacked by the gantry and subsequently picked up again and loaded on to punts in the canal and towed out to the bridge works by launch and tug.

The whole of the 2,000 tons of bridge steel was stacked on the northern side of the canal, whilst the area on the southern side of the canal was used for casting and stacking the reinforced concrete piles used in the foundations. In all some 20,000 tons of bridge construction material were handled by the gantry during the job.

Concrete materials for the 13,067 cubic yards of concrete used in the structure were subjected to close inspection and testing. 13,000 tons of coarse aggregate were supplied by Blue Metal and Gravel Pty. Ltd. That portion required for work on the river was tipped from lorries into bins on the southern bank a little downstream from the bridge and loaded on to the concrete punt by grab operated from the crane punt. The 8,000 tons of sand required were supplied by Nepean Sand & Gravel Ltd. and similarly handled. Cement was supplied by Southern Portland Cement Co. Ltd., some 4,000 tons in all being used. The cement was stored in sheds adjacent to either the pile making plant or the main bins as required.

The steel reinforcement, which varied from $\frac{1}{4}$ in. diameter up to $1\frac{1}{2}$ in. diameter, were supplied by B.H.P. Co. and subjected to testing by the Department. In all, about 1,040 tons of steel reinforcement were used in the bridge.

Despite the difficult period during which construction was in progress, suppliers of vital materials gave excellent service, and no delays were caused by shortage of material or interruption of supplies.

CONSTRUCTION OF SUB~~SUPER~~STRUCTURE.

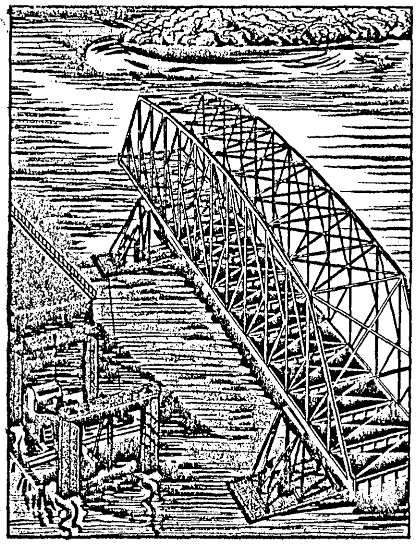
Actual construction work commenced on 1st September, 1938 when excavation for the abutment on the Sydney side was begun. Shortly afterwards excavation for the foundations of Pier 1 at the edge of the water, was commenced. This proved to be a difficult job because fissures in the sandstone allowed water to pour into the excavation and the fissures were very difficult to seal. A diver explored the river bank in an effort to locate and block the sources of leakage, and eventually the foundation was excavated into solid rock, 12 ft. south of the site planned, and the pier base concreted.

Pier No. 2 which is located near the centre of the deep water channel of the river was designed as an open dredged caisson, and was intended to be founded in a bed of sand some 170 ft. below low water level. The caisson is essentially a reinforced concrete shell fitted with a steel cutting edge, and which is sunk by excavating the mud from inside, allowing the weight of the shell to cause it to sink as excavation proceeds.

The cutting edge was laid out on the deck of one of the large punts on 1st November, 1938, and the work of building the concrete shell commenced. The method of building up and launching the caisson from the deck of the punt has already been described in the section dealing with the design.

The caisson was landed on the bottom of the river on 7th November, 1939 by reducing the air pressure below the bulkheads built into the wells. When the caisson was fully supported by the mud of the river bed, the bulkheads

were removed and dredging commenced. By April, 1940 the shell had been built up to 129 ft. long and the cutting edge was 50 ft. below the bed of the river. Then on April 11th, late in the evening, it took a "run" of 53 ft. and dropped out of sight 45 ft. below water level, the drop being exactly vertical.



Location of the sunken caisson and determination of a method for building on to it presented problems which were unique in engineering practice. It was eventually decided to build another section of caisson, floated in a similar manner to the original one, land it on top of the sunken section, and join the two pieces together with reinforced concrete poured under compressed air.

Work on the upper section commenced on 23rd August, 1940 and on February 7th, 1941 it was successfully landed on top of the sunken section. The concrete in the junction was placed on March 29th, and the shell extended to make it 199 ft. long before excavation was resumed. On 8th September, 1941 the caisson "ran" 30 ft. 6 in., but on this occasion practically no inconvenience was caused as the possibility had been foreseen and the concrete was only a short distance below water level, and the surrounding cofferdam could be pumped out.

After further building up and excavation, on 8th June, 1942 the caisson took a third and final "run" of 28 ft. the cutting edge then being 233 ft. below low water level.

When excavation was continued to the cutting edge it was found that the caisson was resting on large boulders. The bottom was cleaned up, all mud and silt being removed by an air lift pump, and rock exposed over portion of the caisson area and a bed of coarse sand and gravel over the remainder. The deepest part of the excavation at the upstream end was 241 ft. 4 in. below low water level. This is within 8 in. of the world's record depth for a bridge foundation, which occurred at Oakland Bay, San Francisco.

An interesting part of this excavation work was carried out by the Department of Main Roads separately from the contract. The boulders were removed by explosive charges which varied in quantity from one plug to 5 lb. of blasting gelatine. Each charge after ignition of the fuse was dropped down through a 4 in. pipe into a hole bored in the rock, the quantity removed being about 10 cubic yards.

To seal the caisson a "plug" of concrete about 26 ft. deep was placed under water by means of special drop bottom buckets. In all 582 cubic yards of concrete were required, placing being carried on continuously for nearly 48 hours, the concrete being mixed in the plant moored near the materials bins, and transported the 500 ft. out to the caisson by a specially rigged punt and then lowered the 240 ft. into position by a crane. This was the biggest continuous pour of concrete in the job.

When the bottom sealing plug was placed, a top sealing plug was poured to form a flat platform on which to build the pier shafts, which were securely bonded into the caisson plug and shell.

The pier work above water level presented no difficulty and the final pour of concrete was placed on 22nd December, 1943, the occasion being one of great satisfaction in seeing the completion of such a difficult part of the job.

The height of the top of the pier above the lowest point of the foundation is 282 ft. 2 in. There are 5,324 cubic yards of concrete in the completed pier, and 243 tons of steel reinforcement, while 6,803 cubic yards of material were excavated during sinking.

Piers 3 to 11 were of a different type, being founded on groups of reinforced concrete piles driven into the river bed. The piles were 20 in. square and varied in length for the different piers from 83 ft. to 110 ft., with a maximum length of 120 ft. for the test pile driven in Pier 3.

The silt of the river bed was excavated for a depth of about 20 ft. inside a sheet steel piling cofferdam, and the piles driven so that the heads were about 6 ft. above the bottom of the excavation. These large and heavy piles — they weighed up to 24 tons each — had to be handled very carefully in a horizontal position, and placed in leaders which could be turned into the vertical position necessary for driving. Driving was effected by an 8 ton hammer, and long ironbark "followers" were used to transmit the blow to the head of the pile below water level.

In all 248 piles were driven in Piers 3 to 11; the total length of the piles was 23,681 ft. The largest pier, Pier 3, had 72 piles in the foundation, their aggregate length being 7,930 ft., just over 1½ miles. The heads of these piles were 50 ft. below water level when driven. These are believed to be the longest conctere piles which have ever been driven so far below water level.

The bases of Piers 3 to 11 were built over the tops of the piles inside a "diving bell", a large welded steel working chamber securely anchored to the foundation piles by the concrete seal poured under water. The working chamber was filled with compressed air, which displaced the water, and allowed all work to be carried out in the dry. Access to the diving bell was through air locks, and the concreting of the base was completed without any disturbance from the water.

This method was evolved by the contractor especially for this job, and is a novel and effective means of constructing foundations on nests of reinforced concrete piles at depths below water level where the ordinary open cofferdam method is at all likely to give trouble.

The diving bell used for Pier 3 was 51 ft. 6 in. long x 30 ft. wide x 15 ft. high, and weighed 40 tons. When filled with compressed air the uplift from the working chamber to be resisted was 700 tons.

Piers 12 to 18 and Abutment B at the northern end of the bridge consisted of six reinforced concrete piles in the piers and four in the abutment with a reinforced concrete headstock to carry the superstructure. The piles were 22 in. square, the total length of the 46 piles being 4,360 ft.; the longest was 102 ft. and weighed 26 tons. The outer piles in the piers on a rake of 1 in 12 and the others vertical were driven by the same methods and machine as for Piers 3 to 11.

SUPERSTRUCTURE.

The erection of the superstructure involved floating the two main spans into position, because of the great depth of water at the section of the bridge where they are situated. The spans were erected on timber falsework resting on temporary wooden piles driven into the river bed on the northern end of the bridge structure, over shallow water. On this falsework a timber travelling gantry was erected, 90 ft. high, its highest point being 130 ft. above water level. This traveller could handle the heaviest piece of the truss spans, namely 22½ tons, and lift it into position, 110 ft. above water level.

The spans were erected at a level approximately equal to that at which they would finally be set, and to the required grade and camber. When the span was riveted up, arrangements

were made to place under it the two 100 ft. punts on which suitable towers had been erected. These punts were drifted in at low tide, and with the rise of the tide, the span was lifted off its erection falsework and drifted clear. The punts were pulled across the river by ropes attached to steam winches, to bring the span opposite the piers on which it was to rest. When the tide had risen again sufficiently the punts were hauled into position between the piers and the span correctly located over the bearings which had been previously set on the tops of the piers. As the tide fell the span came to rest on the bearings and when fully supported the punts and towers were drifted clear.

The operation was very spectacular in that the span measured 440 ft. long x 35 ft. wide x 70 ft. high, and weighed 640 tons, and moved steadily and quietly from its erection false-work across the river to final location on the piers. The first span was floated and placed in position on February 8th/9th, 1944. This portion of the work was necessarily delayed to enable the completion of the exceptionally deep caisson at Pier 2, which carries one end of each of the truss spans. The second span was floated and placed on June 21st/22nd, a little over four months later.

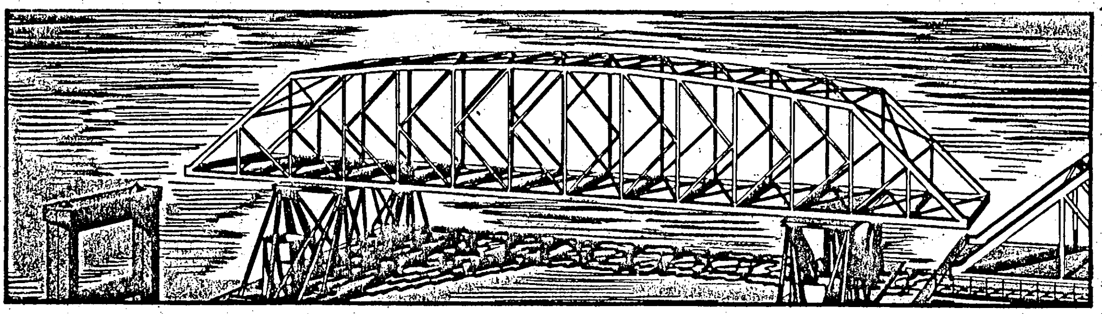
The girders for spans 4 to 11 were delivered by road. Each girder was 90 ft. long x 7 ft. 4 in. deep x 16 in. wide and weighed 17½ tons. The sheer legs lifting plant lifted the girders into position and a crane placed the steel in the floor system, a complete span weighing 54 tons being erected in a day.

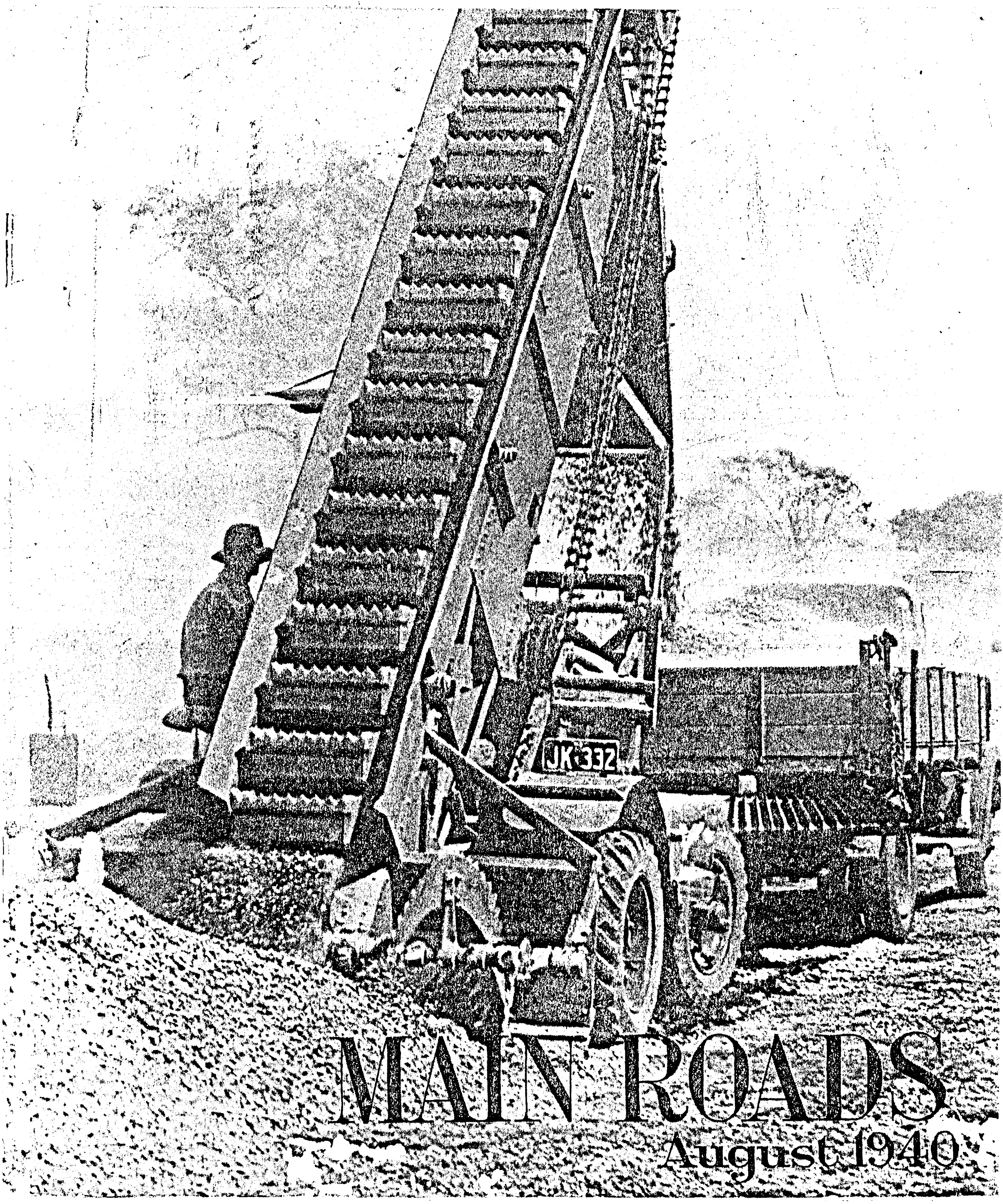
The concrete deck was poured as the super-structure was erected. Spans 5, 6, 7, 8 and 9 were decked before the truss spans were placed, but placing the deck proceeded from the southern end to link up with these spans as soon as the truss spans were in position.

The setback caused by the sudden and un-expected run of the caisson at Pier 2 in April 1940, very seriously interfered with the layout of the job. Instead of Pier 2 being one of the first piers completed in the river section of the job, it was actually the last, and so work was completed between Piers 4 and 8 long before any other part.

No trouble was experienced in "closing" the gaps between the various piers although all the early setting out work had to be done by triangulation from the shore and from tem-porary stagings, and no direct measurements could be made until quite late in the job.

The labour position brought about by war conditions very seriously handicapped the contractor in carrying out the job, and, com-bined with the delays brought about by the exceptional circumstances surrounding the Pier 2 caisson, made the time for completion considerably exceed the original estimate. The whole structure has been faithfully con-structed with the best possible material and the greatest care, and it is to be hoped that the travellers who use the bridge in years to come will pause occasionally to think of and thank those who toiled so arduously to provide the structure in the face of such unusual diffi-culties.




JK 332
MAIN ROADS
August 1940

See p114 re welding for the Hawkesbury River Bridge at Peats Ferry

Welding of Steel Structures.

In recent years the technique of welding steel has been developed to such an extent that welding has become a strong rival to riveting in structural engineering.

During the past six years the Department of Main Roads has made increasing use of the process in lieu of riveting in steel structures. There are various methods of welding in use in different fields of engineering work of which the following are the most common:—

(1) Forge or fire welding.
(2) Gas welding.
(3) Thermit welding.
(4) Resistance welding.
(5) Electric arc welding.

Forge welding is the method which is employed in the blacksmith's shop where the metal is heated in the forge to a plastic stage and hammered on an anvil. For certain classes of work this method has been improved by the development of heating furnaces and power hammers.

In *gas welding* a high temperature flame is produced by igniting a mixture of two gases, usually oxygen and acetylene. The welding is brought about by pre-heating with the torch flame the parts to be welded at the point of contact, and when this base metal is at a suitable temperature, metal is added by melting with the torch flame a filler rod of suitable composition.

Thermit welding is a casting process which employs chemical reaction obtained by igniting a mixture of finely divided aluminium and iron oxide in close proximity to the metal to be welded. During this action the oxygen leaves the iron oxide to combine with the aluminium and the free iron is drawn off at a high temperature into a mould previously prepared round the parts to be welded. These parts are heated both by the burning material and by the metal entering the mould and dissolving in the incoming metal to form when cooled a homogeneous section.

Resistance welding is a heating and squeezing process. The parts to be welded are raised to the temperature of fusion by the passage of an electric current through the junction. When the welding heat has been reached, pressure is applied mechanically to bring about the union.

In *electric arc welding* the parts to be welded are brought to welding temperature at point of contact by the heat liberated at the arc terminals and in the arc stream so that the metals are completely fused into each other, forming a homogeneous mass after cooling. The arc is formed between the work to be welded and an electrode held in a suitable holder. When the arc has been struck the temperature of the work at the point of welding is in the vicinity of 6,500 deg. F. This tremendous heat melts a small pool of metal in the work and extra metal is added from the molten electrode.

The lastmentioned of these processes is the method which is most suitable for use in structural engineering. The following are the types of joint most frequently met with in this class of work:—

(1) Butt and slot welds (see Figs. 1 and 2).
(2) Fillet welds—
 (*a*) end fillets (see Fig. 3).
 (*b*) side fillets (see Fig. 4).

The following table shows the working stresses adopted by the Department for these joints:—

Butt and Slot Welds.

Type of stress.	Working stress in lbs. per sq. in.
Tension	12,500
Compression	12,500
Shear	10,000

Fillet welds.

Type of weld.	Working stress in lbs. per lin. inch of weld.		
	¼ in. weld.	⅜ in. weld.	½ in. weld.
End weld	2,200	3,300	4,500
Side weld	1,800	2,700	3,600

Probably the greatest advantage derived from the use of welding for connections in lieu of riveting lies in the fact that a very appreciable saving in weight

of metal required in any particular work is possible because the loss of section in tension members due to the rivet holes is obviated. Another advantage of welded construction over riveted construction lies in the relative simplicity of the welded work which reduces the cost of maintenance, particularly painting.

In steel bridges of any appreciable size either plate girders or trusses are used. The Department's experience in the development of these two types making use of arc welding in the interests of economy and ease of maintenance is summarised in the following:—

(a) Plate girders.

The conventional type of riveted plate girder with two angle flanges and angle stiffeners has been largely superseded owing to the introduction of new ideas suitable to welded construction. In the welded girders, the edges of web plates are planed and flanges are welded direct to the webs. Plate stiffeners are used, in lieu of the angles in the old riveted types, welded to the webs and flange angles. Accurate grinding of the stiffeners to fit against the flanges in riveted work is not necessary in welded work. The use of welding in steel spans has shown that web plates should be somewhat stiffer than design calculations dictate to counteract the effects of distortion due to heat.

By the use of butt welds in the flanges, it is possible to approximate more closely to the theoretical requirements for sectional area than in the case of riveted work where angles of constant section are usually carried throughout the length of the girder. Where flange plates are welded, it is good practice to complete the flanges first and then to weld the completed flange to the web. If the flange sections are first welded to the web and then butt welded to one another, cooling stresses are high and have been known to crack either the web of the flange plates, and in any event distortion of the web would occur.

After preparation of the full length of flange plates and web separately, the whole girder is assembled and tack welded. When this is completed, and not till then, the continuous welding is put in hand.

From a maintenance point of view the new method of construction is an improvement on the old as the surfaces to be painted are smooth and the usual trouble of rusting round rivet heads is eliminated. The advantage gained by the simplification is, however, somewhat offset by reason of the fact that the surfaces of welds are rough and are therefore not readily cleaned by ordinary methods, and the new metal laid down hot seems subject to the same trouble as rivet heads.

Future improvement in the design of girders lies in the rolling of longer plates to reduce flange splices to a minimum consistent with economical flange area.

More satisfactory connections could also be made if special flange plates were rolled with a projection at centre of one side to which the webs could be welded. These have been used in other parts of the world, but the demand in Australia is as yet too small.

The maximum span so far used for simply supported plate girders is about 90 feet. It is doubtful whether this will be much exceeded because of the difficulty of transporting greater lengths.

In some cases, where rock foundations are available, continuous welded plate-girder design has been adopted, with the field joints riveted. The bridge over the Brogo River on the Prince's Highway near Bega

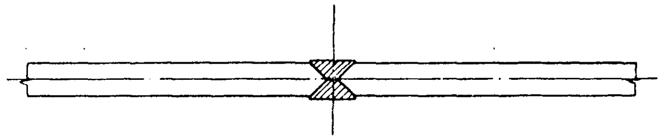


FIG. 1
BUTT WELD
(Section)

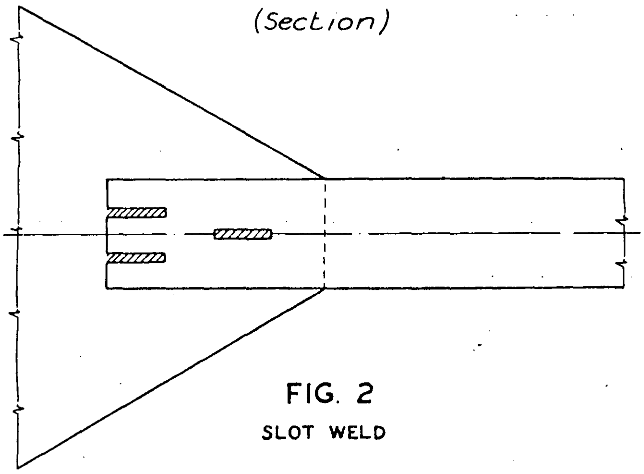


FIG. 2
SLOT WELD

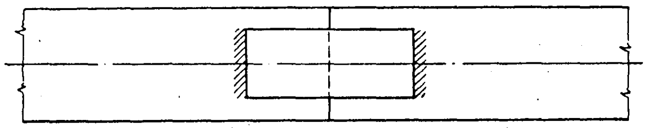


FIG. 3
END FILLET WELD

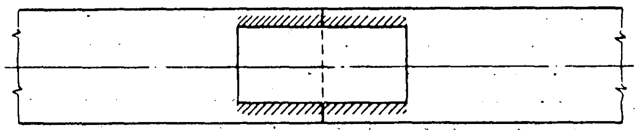


FIG. 4
SIDE FILLET WELD

TYPES OF WELDING

is of this type and consists of three continuous spans of 94 ft., 115 ft. and 94 ft. The access to this site would have been difficult for large pieces of fabricated steel and the design consequently provided for specially short lengths of shop-constructed work.

(b) Trusses.

For some time prior to 1934 various publications in the technical press had claimed economy for welded as compared with riveted construction. At that time the Department, therefore, prepared alternative designs in riveting and welding for the 100-ft. truss span of the bridge over the Manilla River at Barraba and invited tenders on both designs. For shop work the welded design showed a saving in weight of about 20 per cent., and in cost about 13 per cent. The reduced saving in cost was due to slightly higher unit rates for the welded work, at that time new to bridge contractors, as well as because more accurate workmanship and the machining of large plates is required in welded construction.

The unit rates for erection in the field were slightly higher than those for riveted work because special plant and trained men had to be brought long distances to the site for a small amount of welding, and also careful and close supervision was required all the time welding was in progress. For the complete job the saving in cost due to welded construction was 5 per cent.

Field welding is a difficult operation, mainly because of lack of adequate protection from weather. Further difficulty arises because in the field some welding must be overhead, and overhead welding is of necessity somewhat inferior. In some localities also no power is available or may be unable to operate the plant without considerable loss of electrical pressure. For these reasons the most recent development is to use shop welding and field riveting. Under this arrangement it is possible to take full advantage of welding by building up tension members to compensate for the deduction for rivet holes. Further, for compression members it is possible to use "I" sections built up of plates giving a better distribution of metal than is possible for the riveted four-angle "I" section with web plates, while at the same time difficulties connected with field welding are eliminated. No latticing is used in these designs, the top chord leaves being connected by diaphragms. Diaphragms are also used in other compression members where necessary, and tie plates as required for tension members. Heavy portal frames as used in older types of truss which were designed to transfer the whole of the wind load on the upper portion of the truss down the end post to the bearings have been replaced by lighter frames, taking into account the rigidity of the sway frames at each panel point and their ability to transfer their share of the wind load down the verticals, and so to the bearings via the lower lateral system. Thus, welding has effected many modifications and improvements in truss design.

The deck systems on these trusses are similar to the deck system used in the riveted trusses (cross-girders riveted to truss verticals and stringers framed into the cross-girders), except that the cross girders are welded and the stringers are made continuous over two spans. Owing to the increased rigidity of cross girder connections in welded construction, spherical bearings have been adopted to prevent concentration of stress at the inner edge of the bearings as would be the case with the ordinary cylindrical type rocker under cross-girder deflection.

The joints and connections carrying main stresses in the combined riveted and welded trusses are all riveted and can be satisfactorily made in the field by any ordinary erection gang and checked for soundness of work by subsequent inspection.

The field riveted construction eliminates the objection to the use of all welded joints and connections maintained by certain engineers who assert that the heating of the parent metal by the large amount of welding concentrated near the joints reduces the strength of the member even if the weld be adequate. In the combined construction, welding is only used for light longitudinal fillets, diaphragms, etc., so that there is no danger of adversely affecting the strength of the parent metal.

A recent notable work in which welding is being used for all shopwork is the bridge over the Hawkesbury River at Peat's Ferry which includes two 439-ft. truss spans. These trusses are believed to be larger than any other yet attempted on which the bulk of the fabrication is done by welding. The principles of design are the same as for the works described above. The same type of built-up "I" sections are generally used, the only exceptions being the inverted "U" sections in horizontal bottom chords to avoid accumulation of water and the starred angle struts used for the lightly stressed bracing members.

The plates used in forming the "I" and "U" members are very heavy (ranging up to 40 in. x 1½ in. and 30 in. x 2 in.) and cannot be obtained in Australia in the lengths necessary to fabricate each member without intermediate splices. The members have been designed for fabrication by the method developed for plate girders, *i.e.*, the web and flange plates are being fabricated separately by shop butt welding and then brought together and joined by shop fillet welds. The cross girders are welded, of the same type of construction described above for plate girders.

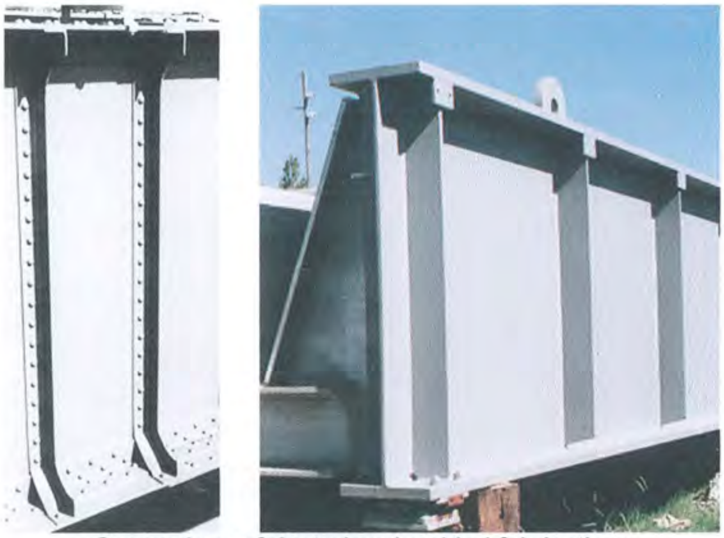
The gussets for web members are riveted to members and serve as splice plates for chords. The gussets for bracing are welded on where possible. The use of welding for these gussets greatly simplified the detailing, clip angles, etc., being eliminated, and bent plates, bent angles, etc. being avoided at the points of change of slope of upper chords. The whole design is built up around these few simple features, and by adoption of riveted connections all the difficulties ordinarily met with in welded truss work are avoided without sacrificing the great advantages inherent in welded construction.

PEATS FERRY BRIDGE

THE WELDED STEEL TRUSSES

Supplementary comments

The extent of welding on the Peats Ferry Bridge trusses can be difficult to appreciate even during a site inspection because welds are long thin fillets/cornices in the corner junction of two plates, in marked contrast to the more visual riveted fabrication.

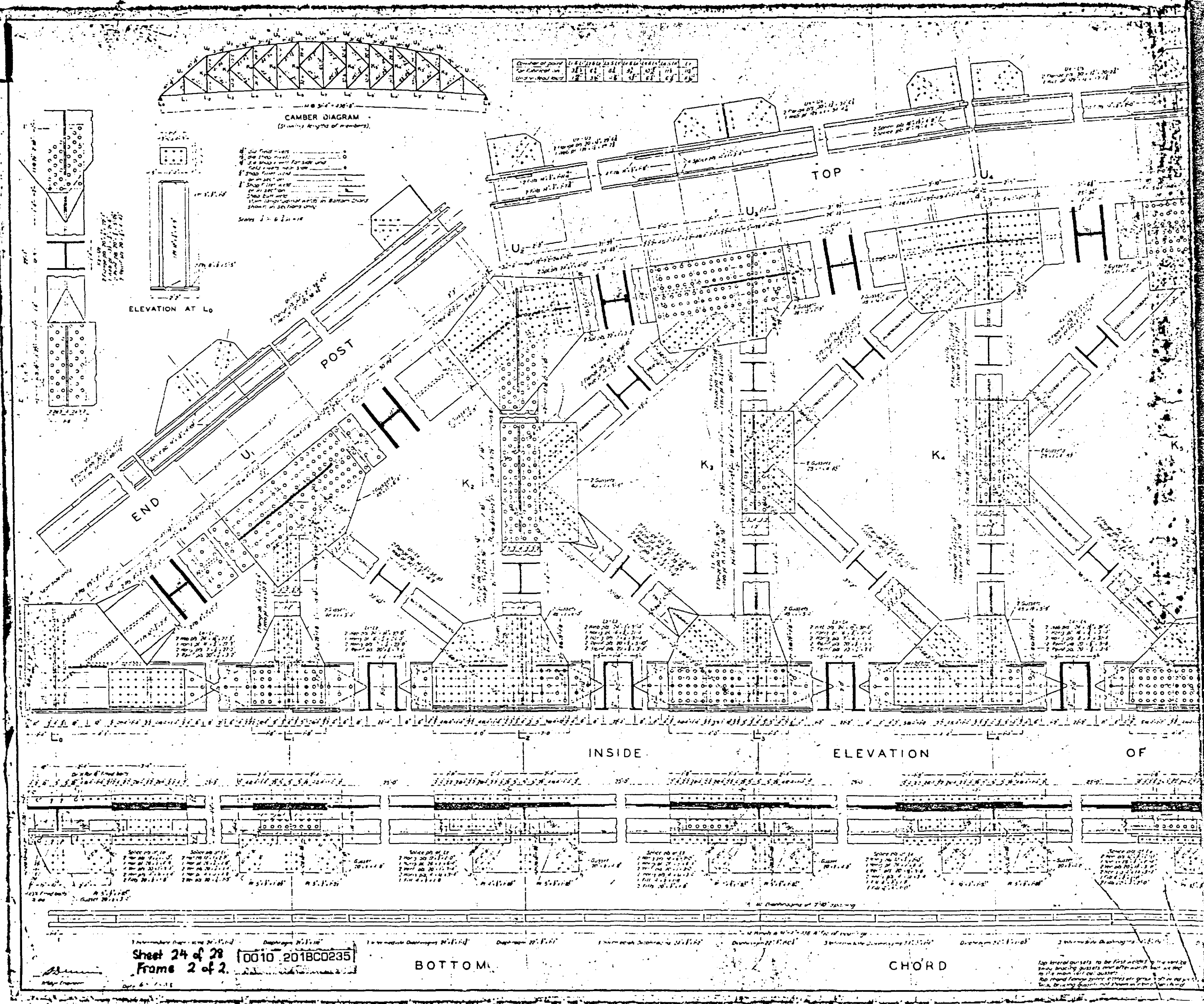


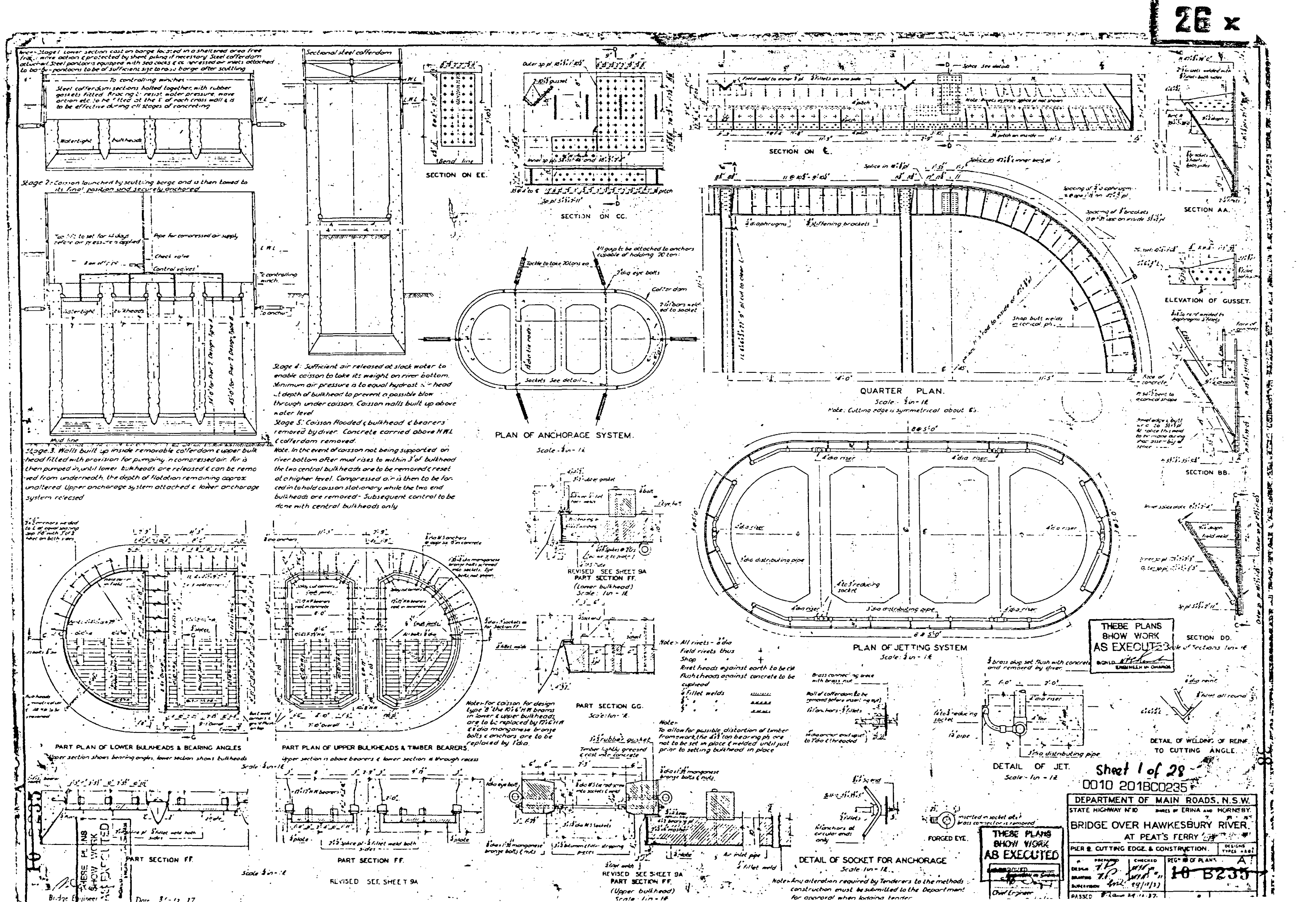
Comparison of riveted and welded fabrications

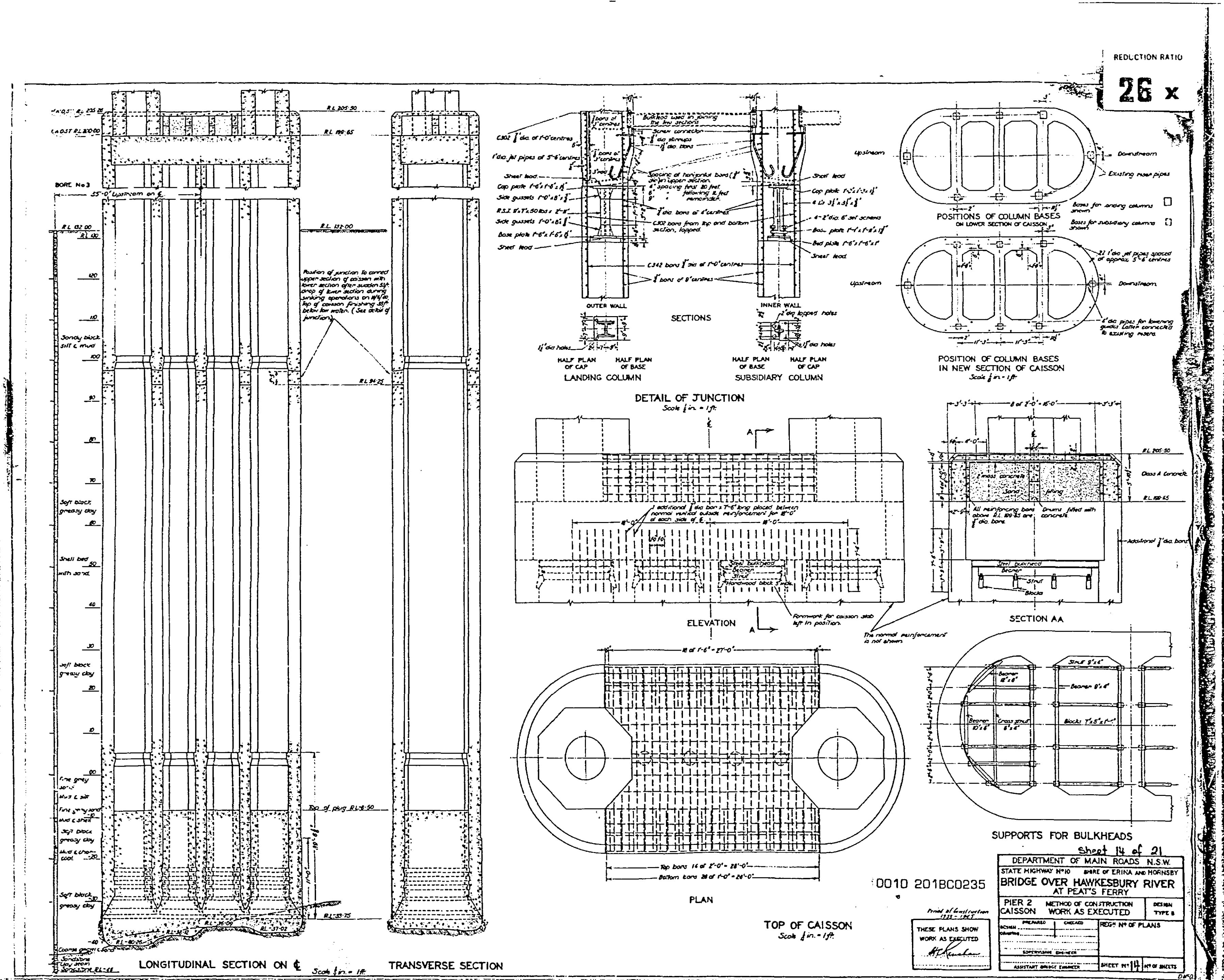
However, on the site, the viewer is quite close to the truss members and can see the clean lines of the welded fabrication.

The design calculations showed that the required cross-sectional areas of the steel members were larger than could be obtained from available ready-rolled RSJs. Fabricated sections were required. DMR experience with welded bridges led to the decision to fabricate the desired sectional areas by welding three plates to form H, I and U-shaped cross-sections. These shapes are shown on the attached drawing.

It's a busy drawing, visually dominated by the riveted field joints but it does show the member shapes in the middle of each member, typically enlarged here. The welds are designated as black blobs on each side of the plate junctions.


CAMBER DIAGRAM
ELEVATION AT L_0
TOP
END POST
U_1
U_2
U_3
U_4
K_2
K_3
K_4
K_5
L_0
INSIDE ELEVATION OF
BOTTOM CHORD
Sheet 24 of 28
Frame 2 of 2.
0010 2018C0235


26 x
Stage 1. Lower section cast on barge located in a sheltered area free from wave action & protected by sheet piling if necessary. Steel cofferdam attached. Steel pontoons equipped with sea cocks & compressed air inlets attached to barge — pontoons to be of sufficient size to raise barge after scuttling.
To controlling winches
Steel cofferdam sections bolted together with rubber gaskets fitted. Bracing to resist water pressure, wave action etc. to be fitted at the ¢ of each cross wall & is to be effective during all stages of concreting.
Watertight bulkheads
Stage 2. Caisson launched by scuttling barge and is then towed to its final position and securely anchored.
Pipe for compressed air supply
Check valve
Control valves
To controlling winch
Stage 3. Walls built up inside removable cofferdam & upper bulkhead fitted with provision for pumping in compressed air. Air is then pumped in, until lower bulkheads are released & can be removed from underneath, the depth of flotation remaining approx. unaltered. Upper anchorage system attached & lower anchorage system released.
Sectional steel cofferdam
Stage 4. Sufficient air released at slack water to enable caisson to take its weight on river bottom. Minimum air pressure is to equal hydrostatic head at depth of bulkhead to prevent a possible blow through under caisson. Caisson walls built up above water level.
Stage 5. Caisson flooded & bulkhead & bearers removed by diver. Concrete carried above H.W.L. & cofferdam removed.
Note. In the event of caisson not being supported on river bottom after mud rises to within 3' of bulkhead the two central bulkheads are to be removed & reset at a higher level. Compressed air is then to be forced in to hold caisson stationary while the two end bulkheads are removed. Subsequent control to be done with central bulkheads only.
SECTION ON EE.
SECTION ON CC.
SECTION ON ¢.
SECTION AA.
ELEVATION OF GUSSET.
SECTION BB.
SECTION DD.
QUARTER PLAN.
Scale - ¼ in - 1 ft
Note. Cutting edge is symmetrical about ¢s.
PLAN OF ANCHORAGE SYSTEM.
Scale - ⅛ in - 1 ft
Tackle to take 70 tons ea.
Cofferdam
PLAN OF JETTING SYSTEM
Scale - ⅛ in - 1 ft
4" dia riser
3" dia distributing pipe
REVISED SEE SHEET 9A
PART SECTION FF.
(Lower bulkhead)
Scale 1 in - 1 ft
PART SECTION GG.
Scale 1 in - 1 ft
Note - All rivets - ⅞ dia
Field rivets thus
Shop
Rivet heads against earth to be countersunk
Flush heads against concrete to be cupheaded
Fillet welds
Note - For caisson for design type "B" the 10 x 6 H.M. beams in lower & upper bulkheads are to be replaced by 12 x 6 H.M. & ⅞ dia manganese bronze bolts & anchors are to be replaced by 1 dia.
Note - To allow for possible distortion of timber framework the 4½" ton bearing pls are not to be set in place (welded) until just prior to setting bulkhead in place.
PART PLAN OF LOWER BULKHEADS & BEARING ANGLES
Upper section shows bearing angles, lower section shows bulkheads
PART PLAN OF UPPER BULKHEADS & TIMBER BEARERS
Upper section is above bearers & lower section is through recess
PART SECTION FF.
PART SECTION FF.
REVISED SEE SHEET 9A
DETAIL OF SOCKET FOR ANCHORAGE
Scale - 1 in - 1 ft
REVISED SEE SHEET 9A
PART SECTION FF.
(Upper bulkhead)
Scale - 1 in - 1 ft
FORGED EYE.
DETAIL OF JET.
Scale - 1 in - 1 ft
DETAIL OF WELDING OF REINF. TO CUTTING ANGLE.
Note - Any alteration required by Tenderers to the methods of construction must be submitted to the Department for approval when lodging tender.
THESE PLANS SHOW WORK AS EXECUTED
Engineer in Charge
THESE PLANS SHOW WORK AS EXECUTED
Sheet 1 of 28
0010 201BC0235
DEPARTMENT OF MAIN ROADS, N.S.W.
STATE HIGHWAY No 10 SHIRES OF ERINA AND HORNSBY
BRIDGE OVER HAWKESBURY RIVER
AT PEAT'S FERRY
PIER 2. CUTTING EDGE & CONSTRUCTION.
Chief Engineer
Bridge Engineer
10 B235
A



REDUCTION RATIO
26 x
LONGITUDINAL SECTION ON ℄
TRANSVERSE SECTION
Scale 1/8 in. = 1 ft.
BORE No 3
DETAIL OF JUNCTION
SECTIONS
OUTER WALL
INNER WALL
HALF PLAN OF CAP
HALF PLAN OF BASE
LANDING COLUMN
SUBSIDIARY COLUMN
POSITIONS OF COLUMN BASES ON LOWER SECTION OF CAISSON
POSITION OF COLUMN BASES IN NEW SECTION OF CAISSON
Upstream
Downstream
ELEVATION
SECTION AA
PLAN
TOP OF CAISSON
SUPPORTS FOR BULKHEADS
Sheet 14 of 21
DEPARTMENT OF MAIN ROADS N.S.W.
STATE HIGHWAY No 10
SHIRE OF ERINA AND HORNSBY
BRIDGE OVER HAWKESBURY RIVER
AT PEAT'S FERRY
PIER 2 CAISSON
METHOD OF CONSTRUCTION
WORK AS EXECUTED
DESIGN TYPE B
Period of Construction 1938 - 1945
THESE PLANS SHOW WORK AS EXECUTED
REGD No OF PLANS
SUPERVISING ENGINEER
ASSISTANT BRIDGE ENGINEER
SHEET No 14
No OF SHEETS
0010 201BC0235
MICROBOX

PEATS FERRY BRIDGE

THE CAISSON FOR THE MAIN PIER AND ITS 'RUNS'

Supplementary comments

The preceding two drawings show the basic features of a caisson, a common item of bridge construction world wide for very deep foundations (150 – 250 feet) in major waterways.

Essentially it is a multi-cell vertical concrete tube that is progressively extended vertically as the tube sinks, see page 7 of the DMR Booklet for this sinking process.

At the base of the caisson is a circumferential, tapered steel cutting ring/edge (right hand side of sheet 1) upon which successive sections/lifts of the concrete tube are cast until the cutting edge reaches the river bed and settles to a stable depth with the top of the tube above water.

Further sinking occurs due to a combination of, internal dredging of the tube, which reduces the frictional resistance of the bed material adhering to the inside surfaces of the inner cells and, building up new concrete sections of the tube above water level, which increases the weight of the caisson thus causing more sinking.

It's a delicate balancing process depending on the variability of the bed materials. For resistive materials, high extensions of the tube may have to be built for more weight. Sometimes, high-pressure water jets have to be applied to the cutting edge to loosen stiff material. If sinking stops, it usually requires sealing the top of the tube to create a working chamber under compressed air and sending workmen down to clear the obstruction.

However for weak bed materials, the total weight of the caisson exceeds the frictional resistance and the caisson sinks unaided, it's called a 'run'. The attachment describes the three 'runs' that occurred at the Peats Ferry site.

Eventually the caisson reaches bedrock or an acceptable solid strata. Sometimes the founding base has to be levelled by hammer dredging or under compressed air working.

With the caisson bedded, the bottom internal 20-30 feet is sealed by a concrete plug (left hand side of sheet 14) placed by an under-water concreting method.

The rest of the vertical interior is usually filled with fresh water until a few feet below the top of the tube where another plug/cap is cast, and upon this the visible pier is built.

The Roadmakers

Even with such a limited programme of construction and improvement, the Department had difficulty in carrying works through to completion, as apart from the diversion of manpower and plant, delays were experienced in obtaining essential materials, such as steel and timber for bridgeworks. There was little bridge-building activity other than the replacement of structures destroyed by floods and the strengthening of bridges to meet military requirements. As far as road maintenance was concerned, the shortage of bituminous materials prevented the surfacing or resurfacing of pavements which, under normal conditions, would be regarded as essential. On gravel roads, resheeting was often not carried out when required and minor improvements throughout the system had to be deferred.[8]

A MONUMENT TO SKILL AND ENERGY

Shortly before the victory was won in Europe, a ceremony was held on 5th May 1945 to mark the end of another long drawn-out struggle and that was the building of the bridge over the Hawkesbury River at Peat's Ferry where, a hundred years earlier, George Peat had established a crossing of this wide waterway. Among the tablets unveiled on that day was one which read: *"This bridge was provided by the people of New South Wales for the use and convenience of man. It was built of Australian materials by Australian workmen and it stands as a monument to the skill and energy of the builders".*

Recording the difficulties and the dramatic moments of construction, the Gosford Times of 8th May 1945 made this report.

"The 'bed' of the Hawkesbury River at Peat's Ferry was known to consist of black mud at a depth of 60 feet. Below that was a layer of dark, firm clay, and, still lower, coarse sand. Originally, it was planned to sink the caisson supporting the two truss spans to a depth of 170 feet below water level into this sand bed.

But Nature had a trick up her sleeve to defeat man's expectations.

The caisson, a huge shell of steel and reinforced concrete, fitted with a steel cutting edge, was to be sunk by dredging the mud from inside.

On November 7, 1939, the caisson was landed on the bottom of the river. By April 1940, the shell weighed 4400 tons and had been built up to 129 feet long. The cutting edge was 50 feet below the bed of the river. Then on April 11, late in the evening, men on top of the caisson, 8 feet above the water, were alarmed to see water rising rapidly up the walls. It meant that the huge mass of reinforced concrete was rapidly sinking. The soft mud had been unable to take the weight. The men on the caisson just had time to jump on to the punt before the top of the caisson disappeared beneath the water. Fortunately, the drop was exactly vertical; but the caisson did not stop until its top was 45 feet below water.

Failure, final and complete, stared the bridge builders in the face. Here was a problem unique in engineering practice ...

The sunken caisson was located. Another section of caisson was constructed, floated into position as the first had been, placed right on top of the first section and joined thereto, 50 feet below the water...

Everything seemed right at last. The concrete in the junction was placed on March 29 and the shell extended to make it 199 feet long before excavation was resumed. The weight of the caisson was now up to 7000 tons.

Again Nature stepped into show that Old Man Hawkesbury was not yet beaten by the bridge builders.

On September 8, 1941, the two section caisson plunged again. With a roar, a huge mushroom of water, driven out by the mud, rushed from the caisson. Down it went for 30ft. 6in. But this time the bridge builders, having been pre-warned, were not taken by surprise. The concrete was only a short distance below water level, and the surrounding cofferdam could be pumped out.

By June 8, 1942, the assembled caisson weighed 8100 tons and was 35 feet longer. That day it took its third and final run of 28 feet, the cutting edge being 233 feet below low water level and resting on rock bottom. The top of the caisson was at low water level.

Although mud had to be dredged, rock bored, blasted and excavated, the rest of the work was comparatively simple. Finally, the caisson was secured for ever on solid rock and sealed with a 'plug' of 582 cubic yards of concrete.

The vital pier of the Peat's Ferry Bridge was secure at last, 241ft. 4in. below low water level..This is within 8 inches of the world's record depth for a bridge foundation — the Bay Bridge between San Francisco and Oakland.

A book could be written on the building of this bridge and the men who built it... There was the night, for instance, when the first section of the caisson, floating quietly (it had a false bottom, later to be blown off by compressed air) broke with a bang when the steel hawsers snapped and it sailed upstream. It was chased by a launch. Then the tide turned and away it went downstream in the direction of the railway bridge—800 tons of ungoverned steel and concrete, heading for a grand smash up. A mile from the bridge a D.M.R. ferry and a Balgue Constructions' tug caught and roped it ....

The largest diving bell in the world, in which 18 men worked comfortably, was used to concrete together the heads of the concrete piles to concrete together the heads of the concrete piles for the bridge's northern end. It was 51ft. 6in. long x 30ft. wide x 15ft. high, and weighed 40 tons ...

The bridge superstructure provides another story in itself. Impressive and spectacular was the operation of floating the huge truss spans on punts into position at high tide. As the tide fell each span came to rest on the bearings and the punts which bore it drifted clear. Each span measured 440ft. long x 35ft. wide x 70ft. high, and weighed 640 tons.

The first span was floated and placed in position on February 8/9, 1944 and the second on June 21/22 ...

Designed to the last detail by the New South Wales Department of Main Roads, the superstructure fabricated by the Clyde Engineering Company Ltd., built under the supervision of the D.M.R. by Balgue Constructions Pty. Ltd., whose engineers and workmen proved their high skill and determination by the manner in which each did his share of the work, to each and to all credit is due for a grand job. The obstacles they overcame are the measure of their achievement".[9]